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TECHNICAL REPORT
NATICK/TR-87/017

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TRAY PACK PROTOTYPE PLANT DESIGN

BY

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This project report describes the engineering design of a prototype production facility for the automated manufacture and assembly of Tray Pack foods for Army field feeding use. The plant was designed to produce 44 menu items for a total production rate of 17 million Tray Packs/year on automated assembly lines designed to operate at 20 cpm. The report describes the schematic engineering design of the entire facility which includes the following activity areas: I. Receiving Warehouse, II. Preparation Area, III. Filling Lines, IV. Sterilization Area, V. Packaging and Labelling Area, VI. Shipping Warehouse, and VII. Administrative/Staffing Areas. The overall size of the plant is 210,081 square feet. A cost analysis of the plant, personnel and equipment together with appendices describing equipment suppliers, specialized automation equipment, and related software products is also included.

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PREFACE

Tray Pack foods are one of the primary ration sources for the new Army Combat Field Feeding System. Presently, there is a very small commercial market for Tray Pack foods and a very limited production base. The total production of the companies manufacturing Tray Pack foods have a maximum annual capacity of 5 to 6 million trays per year. This production rate falls far short of the projected Army requirements of 10 million Tray Packs in FY 1987 and subsequent years. Mobilization needs would even be more demanding.

The purpose of this study was to draft plans for a plant to produce Tray Packs at high speeds in an efficient and effective manner to meet future production demands. The University of Massachusetts Department of Industrial Engineering and Operations Research was charged to conduct the study. The work was performed under Project *1L162724AH94, Joint Services Food/Nutrition Technology Task Area B5 – Subsistence Technology, Technical Effort – Food Processing and Preservation Techniques, Producibility of Thermostabilized Combat Rations*. The Project Officer was Joseph W. Szczeblowski.

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I wish to thank Joe Szczeblowski, Curt Blodgett, Wayne Swantak and the other staff members of Natick Research Development & Engineering Center (NRDEC) for their support, comments, directions and criticism throughout this project. I also wish to thank all the manufacturers who have donated their time, information and comments as the design of the Tray Pack facility unfolded. Also special thanks go to Chet Lisak, Seth Hall, Ashook Vishnu and Tarik Abou-Raya of the Engineering Computer Station of the University of Massachusetts who helped with the computer graphics drawings, which became essential to the final project report.

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CHAPTER 1. Introduction

A. Overview

In an initial report to NRDEC[1] a team of researchers from The University of Massachusetts was asked by NRDEC to analyze the Producibility, Engineering and Planning (PEP) of Tray Pack foods for the Armed Services. The UMass PEP team observed, reviewed on-site, discussed and evaluated all but one of the seven current producers of Tray Packs for the military. A wide range of equipment and methods along with many common problem characteristics was found among the various production lines. All producers used *manual* methods to handle Tray Packs (empty and filled), none used automatic or machine-assisted fillers for transferring food materials to Tray Packs, and powered conveyors saw limited use, if ever. Almost all producers had definite feelings about production rates they could achieve. The limited opportunities to test their figures demonstrated that they were usually optimistic and sometimes they were way off the mark. There was no evidence that any production line observed had been designed in an engineering sense. The manufacturing expertise that existed at each location was used to set-up production lines, but no engineered lines existed, such as would occur with sophisticated fillers, conveyors, weighing apparatus, etc. normally found in high-speed canning lines.

In response to the findings of the PEP team, the following report is a preliminary examination of the requirements for a prototype facility to produce Tray Packs at a minimum line rate of 20 trays per minute. The design philosophy underlying this report is twofold. *First* of all, general design guidelines for an *ideal* or prototype Tray Pack facility will be developed. In this way, the prototype facility provides the *system* backdrop essential to the development of the high-speed line rates. *Second*, within the context of the *ideal* facility, specific engineering design drawings will be developed for the automated filling lines for Tray Packs. Together the design guidelines for the prototype facility along with the detailed engineering drawings provide a practical as well as stimulating backdrop for the planning, design and manufacturing of Tray Packs.

In the first part of this report, Chapters 1 and 2, the overall design of the facility is examined, the major cluster areas of activities are identified and their interrelationships are specified. In the second half of this report, Chapters 3–9, the detailed requirements of the activities and equipment items that make up the facility are identified, quantified and presented. Finally, Chapter 10 presents a detailed cost estimate of the facility together with some additional recommendations and issues for further study and analysis.

B. Project Objectives

The objectives of this study within the design philosophy stated in the Overview section of this Chapter are essentially the following:

- o Develop an engineering design for an *ideal* Tray Pack production facility including layout drawings, listing of personnel, activities, equipment, costs and services for its operation.
- o Engineering drawings for the filling lines shall provide complete detail enabling major increases in production rates while keeping processing lines sufficiently versatile to handle a variety of food items.
- o Production systems shall be capable of producing 44 basic items and 29 alternate items. The plant will be initially designed to produce 17 million trays per year.

- o Minimum production line rates shall be 20 trays/minute.
- o Automation shall be maximized wherever possible for all unit operations.

C. Basic Assumptions

For this study, the following assumptions were postulated in order to set the groundwork for developing the facility requirements, both in terms of the size of the facility, number of personnel and equipment necessary to operate the facility.

1. Menu Breakdown

For functional reasons, the 44 main and 29 alternate items are segmented into four food categories based on their manufacturability requirements. These four food groups are the following:

One Step Filling (19 food items)
Two Step Filling (44 food items)
Hand Placement (3 food items)
Oven Baked (7 food items)

These basic food groups were derived from information available within NRDEC with regards to the manufacturability of the Tray Pack menu items. Obviously, the division of the menu items into the food groups may not be sacrosanct, however, it provides a useful morphological stepping stone and will serve as a useful guide to determining the number of filling lines requisite in the production facility. The four functional categories of items are displayed along with the actual items from the main and alternate menus in the tables below:

Functional Category	*Main Menu Items*	*Alternate Menu Items*
One Step Filling	o Beef Stew	o Chili Con Carne
	o BBQ Beef	o Chicken w/ Noodles
	o Creamed Gr. Beef	o Chicken Stew w/Gravy
	o Breakfast Bake	o Sweet Creamed Corn
	o Eggs w/Ham	o Blueberry Dessert
	o Chicken ala king	o Cherry Dessert
	* Egg Loaf w/Mushrooms*	
	o Potato Salad	
	* Orange Nut Cake*	
	* Cherry Nut Cake*	
	o Apple Sauce	
	o Apple Dessert	
	o Chocolate Pudding	
Total One-Step Items	*13 Main Menu Items*	*6 Alterante Items*
Two Step Menu Items	o Beef Pepper Steak	o Pork Slices w/Gravy
	o Turkey Sl.w/Gravy	o Swedish Meatballs
	o Ham Slices	o Beef Pot Roast
	o Franks in Brine	o Spaghetti w/Meatballs
	o Meatloaf w/Gravy	o Swiss Steak
	o Canadian Bacon	o BBQ Pork
	o Pork Sausage Links	o Chicken Cacciatore
	o Roast Beef w/Gravy	o Chicken Breasts
	o Roast Chicken	o Beef Tips w/Gravy
	* Egg Loaf w/Cheese*	o Beef and Macaroni
	o Escalloped Potat.	o Spanish Rice

	o Beans w/Pork	o Macaroni Salad
	o Macaroni/Cheese	o Potat/Chicken Sauce
	o Buttered Potat.	o Glazed Carrots
	o Buttered Noodles	o Peas and Carrots
	o White Rice	o Lima Beans
	o Sweet Potat.	o Stewed Tomatoes
	o 3-Bean Salad	
	o Green Beans	
	o Peas/Mushrooms	
	o Whole Kernel Corn	
	o Sliced Carrots	
	o Mixed Vegetables	
	o Sliced Peaches	
	o Sliced Pears	
	o Fruit Cocktail	
Total Two-Step	*27 Main Menu Items*	*17 Alternate Items*
Hand Placement Items	o	o Lasagne
	o	o Stuffed Peppers
	o	o Stuffed Cabbage
Total Hand Placement	*0 Main Menu Items*	*3 Alternate Items*
Oven Baked Items	o Spice Cake	o Marble Cake
	o Chocolate Cake	o Pound Cake
	o Apple Coffee Cake	o Fruit Cake
	o Blueberry Cake	
Total Baked Items	*4 main Menu Items*	*3 Alternate Items*

**n.b.* These starred items have been deleted from the program. Replacements are to be retested in the future, however, it will be assumed that comparable menu items will replace them.

These categories are essential to the manufacturing process because they begin to dictate the line design requirements, amounts of equipment and personnel necessary to satisfy the overall production demand of 17 million trays per year.

For the present, we will assume that the 44 main menu items are the number of essential items produced at the facility, in other words, the 29 alternate items simply act as substitutes in the above 44 main menu items. Thus, the number of lines, square footage allocations, equipment and staff are determined by the 44 main items.

2. Number of Filling Lines

Given the previous breakdown of menu items according to their functional classification, the following production volumes are required of the 44 main menu items:

One Step Filling Line:	4,833,410 Tray Packs	(28 %)
Two-Step Filling Line:	9,333,380 Tray Packs	(55 %)
Hand Placement:	0 Tray Packs	(0 %)
Oven Bake Filling Line:	2,833,210 Tray Packs	(17 %)
Total Volume:	**17,000,000 Tray Packs**	**(100 %)**

The figure of 17,000,000 Tray Packs is a forecast for fiscal year 1988 that was based on data available in 1984. While the expected volume at the time of writing this report is expected to be somewhat lower than this 17 million figure, it will probably be in the neighborhood of 10.5 million, which is still a siseable amount and one where the automated production of Tray Packs becomes critical.*

As we shall see, the technology of producing Tray Packs greatly affects the number of lines, line rates, and the production environment which will emerge. From the above analysis, there are two essential types of lines: 1) Retort line and 2) Oven Bake line. The Retort line should be capable of handling the One-Step and Two-Step menu items described above. The retort line is configured to handle the different types of filling equipment necessary for the One-Step and Two-Step menu items. As the report will demonstrate, one highly automated retort filling line operating at 40 cans per minute (cpm) will be able to produce the total retortable menu items demand. The other line will accommodate the oven bake production requirements.

This preliminary analysis does not include the possibility of machine breakdowns, spillage and wastage, production overruns or other factors which directly affect production of the required number of trays. For instance, even though no hand-placed items are contemplated in the 44 main menu items, in the foreseeable future, production of these items could certainly occur. Thus, engineers must design the line layouts so that hand-placement items could be produced. In the upcoming section of this report where the line layouts are presented, some of this line design flexibility is incorporated.

3. Ten Day Menu Cycle

In order to assess the quantities of food items to be stored in both the Receiving and Shipping Warehouses, an assumption must be made with regards to the type of production schedule at which the plant will operate. Demand for Tray Packs currently revolves around a 10 day menu cycle, so production of items should naturally follow demand. Therefore, the 10 day menu cycle will be adopted as the key production cycle. There are some additional constraints on the Shipping Warehouse because a 20 day incubation period is required for production lots prior to shipment according to USDA standards. While there is some flexibility with regards to this 20 day holding period, the author has designed the plant for this maximum incubation period.

Weekend — [Monday - Friday] — Weekend — [Monday - Friday] — Weekend
— 5 working days —.............. — 5 working days —

* For a reference to this 10.5 million procurement figure, see the recent forecast by Capt. Donald S. Parsons in Reference #2.

Thus, the 44 items produced during a production cycle (i.e. 10 working days), arguably should follow the percentages required by the 10 day menu cycle. For example, the number of Beef Stew Trays produced during a 10 day menu cycle, would be 14,529 trays or around 6 hours of production on a line of 40 cpm. This 10 day production cycle will also regulate the inventory of raw materials and storage of trays in the shipping warehouse. The breakdown in Table 1 illustrates the production requirements and number of trays produced per 10 day cycle for each of the 44 items.

Table 1. Ten-Day Cycle Productions, 44 Main Menu Items

Main Menu Items	*Trays/Cycle*	*Prod-Hours*
One-Step Items		
o Beef Stew	14,529	6.05
o BBQ Beef	12,592	5.25
o Creamed Gr. Beef	25,184	10.49
o Breakfast Bake	18,888	7.87
o Eggs w/Ham	18,888	7.87
o Chicken ala king	12,592	5.25
o Egg loaf w/Mushrms*	18,888	7.87
o Potato Salad	7,555	3.15
o Orange Nut Cake*	9,444	3.94
o Cherry Nut Cake*	9,444	3.94
o Apple Sauce	15,110	6.29
o Apple Dessert	7,555	3.18
o Chocolate Pudding	15,110	6.29
Sub-Total	*185,779 trays*	*77.40 hours*
Two-Step Items		
o Beef Pepper Steak	12,592	5.25
o Turkey Sl.w/Gravy	10,493	4.37
o Ham Slices	10,493	4.37
o Franks in Brine	8,585	3.58
o Meatloaf w/Gravy	9,444	3.94
o Canadian Bacon	31,480	13.12
o Pork Sausage Links	18,888	7.87
o Roast Beef w/Gravy	9,444	3.94
o Roast Chicken	12,592	5.25
o Egg Loaf w/Cheese*	18,888	7.87
o Escalloped Potat.	7,555	3.15
o Beans w/Pork	7,555	3.15
o Macaroni/Cheese	15,740	6.56
o Buttered Potat.	15,110	6.29
o Buttered Noodles	15,110	6.29
o White Rice	30,220	12.59
o Sweet Potat.	15,110	6.29
o 3-Bean Salad	9,444	3.94
o Green Beans	15,110	6.29
o Peas/Mushrooms	15,110	6.29
o Whole Kernel Corn	15,110	6.29
o Sliced Carrots	7,555	3.15
o Mixed Vegetables	15,110	6.29
o Sliced Peaches	22,665	9.44
o Sliced Pears	7,555	3.15
o Fruit Cocktail	30,220	12.59
o Diced Pineapple	15,110	6.29
Sub-Total	*402,288 trays*	*167.62 hours*

Oven Baked Items		
o Spice Cake	9,440	7.87
o Chocolate Cake	18,888	15.74
o Apple Coffee Cake	28,332	23.61
o Blueberry Cake	37,776	31.48
Sub-Total	*94,436 trays*	*78.69 hours*
Total Menu Items	*682,503 trays*	*323.71 hours*

**n.b.* even though the starred items have been deleted from the main menu, equivalent substitutes are being developed and as an estimate of likely production of these new items, the older values will be assumed for these new production items for the moment.

Since there will be two separate lines, one for the retortable items and the other for the oven-bake items, they will have to operate 24 hours per day given the 250 days per year work schedule. Obviously, the 250 days is a conservative estimate for the operation of a highly automated production facility, so no real problem should occur for meeting this demand over the year.

The Oven Bake line is designed to handle a line rate of 20 cpm, and since the volume on this line is much smaller, it should be able to meet production requirements without much trouble. The Oven Bake line is also designed to operate 24 hours per day, yet its line throughput rate can be the lower bound of 20 cpm.

4. Batch Plant Operation

Even though there will be a great deal of automation in the design of the equipment and material handling system of the plant, due to the large number of products (44 main and 29 alternate tray items), the plant will basically operate as a batch processing operation as opposed to a continuous facility. As production volume increases, items may be produced at such rates that additional lines may be required which are dedicated to specific menu items. Nevertheless, due to the multiple product orientation, the overall plant will still function as a batch plant because the sterilization process can only be set up for a specific menu item at one time. Loading and unloading of the trays out of the retort trolleys may be automated to a point where this time is minimised, however, the plant will still function esentially as a batch production facility.

C H A P T E R 2. Facility Overview

A. Activity Description

This Chapter will give an overview of the entire Tray Pack facility design including the type of activities, their interrelationships and general factors relating to the overall operation of the plant. As for the facility itself, there are essentially seven different activity clusters which make up the facility. These are the following:

I. *Receiving Warehouse*
II. *Preparation Area*
III. *Filling Lines*
IV. *Sterilization Area*
V. *Packaging and Labelling Area*
VI. *Shipping Warehouse*
VII. *Administrative/ Staffing Areas*

B. Activity Relationships

The *Receiving Warehouse* accommodates the raw materials, trays and lids and other commodities necessary in the manufacturing process. The warehouse is viewed as a separate entity with as much automation as possible yet integrally linked to the Preparation Area and other parts of the plant through the material handling system of Automated Guided Vehicle System (AGVS) trucks, conveyors, and forklift trucks.

The *Preparation Area* includes the necessary cooking and baking as well as slicing, dicing, and preparation activities associated with preparing the 44 main and 29 alternate menu items for the assembly process. Centralisation of the equipment in this area while allowing for material handling flow around the Preparation Area is key to its location and design within the plant.

The *Filling Area* includes the assembly, crimping, closing and seaming operations of the Tray Packs. As will be seen, the high-speed filling line for the retortable items is integrally linked to a continuous food steriliser so as to emulate as closely as possible a continuous manufacturing operation. The Oven Bake line is a separate entity but linked with the Retort line via the packaging and palletising operations.

The *Sterilization Area* houses a continuous food steriliser designed to accommodate the high-speed assembly line within the plant producing retortable items at 40 cans per minute. For one hour of production, this would amount to a maximum of 2400 cans per hour. Other types of batch oriented retort equipment could be utilised but there are capacity and operational concerns that arise due to the number of batch retorts required to handle the 2400 cans/hour and the capital and operating expenses that would accrue from these smaller retorts. One of the main features of the continuous food steriliser is the automated loading and unloading conveyors that smooth the production process.

The *Packaging Area* houses the automated equipment for labelling, boxing and palletising the cans. In addition, the USDA Laboratory as well as the Incubation room for storing the can samples from the production runs is located within this area. The Packaging area is directly adjacent to the Filling, Sterilisation areas, and Shipping Warehouse.

The *Shipping Warehouse* includes general storage for Tray Packs, storage for damaged cans, the shipping offices for rail and truck operations as well as staging areas and truck docks.

The *Administrative and Staffing* areas include the Engineering offices, Quality Assurance area, Test Kitchen, Management offices, Secretarial, Visitor Reception, Cafeteria, Lounge Maintenance Shop and staff locker and personal storage areas.

Figure 1 provides a translation of the seven areas of the plant into a relationship diagram indicating the relative positioning and adjacencies required for the overall plant layout.

Figure 1, illustrates the linear, continuous flow process which should underlie the facility design. Multiple parallel lines would be developed for the products from the preparation on through the packaging of the trays with the Receiving and Shipping warehouses as the end points of this linear production process. The schematic drawing on the next page, Figure 2, indicates the general physical arrangement of the major spaces necessary in the Tray Pack production facility and acts as a direct translation of the operational requirements specified in Figure 1.

Figure 2 represents the overall scheme for the plant layout. Other alternatives are possible but as they deviate from the above arrangement, tradeoffs in efficiency, material handling costs, and flexibility in plant expansion will occur.

The overall scheme represents a building area of 210,081 square feet. 189,060 square feet are dedicated to the Warehousing and Production areas while 21,021 square feet are provided for the Administrative functions.

C. Schematic Plant Layout

Some items of interest on the layout diagram are worth discussing. First of all, as has been stated before, the two warehouses for Receiving and Shipping are designed to be distinctly separate to reduce possible traffic conflicts in the material handling sytem that could arise due to the AGVS trucks, conveyors, forklift trucks, and movement of personnel and goods throughout the factory. This is an *essential* design concept underlying the plant layout. Second of all, the Warehouses are designed to be as square in shape as possible in order to minimise material handling costs. Third, the movement of goods from the Preparation area through the Filling area and onto the Sterilisation area is designed to accommodate the multiple products in a linear flow process with as little overlapping and line conflicts as possible. Finally, the Administrative and Staffing areas are to one side of the entire plant so that plant expansion to the north can occur without unnecessarily disrupting the manufacturing process. On the remaining pages of this document, the detailed schematic development of each area within the plant will take shape according to the seven major areas identified previously in the first part of the report.

I) Receiving Warehouse
(Raw material receiving, Freezer and Refrigeration)

II) Preparation Area
(Ovens, Kettles, and General food preparation)

III) Filling Area
(Filling, Crimping and Closing of cans)

IV) Retorting Area
(Sterilization and Can Washing)

V) Packaging Area
(Labelling, Boxing and Palletizing of cans)

VI) Shipping Warehouse

VII) Administration/Staffing

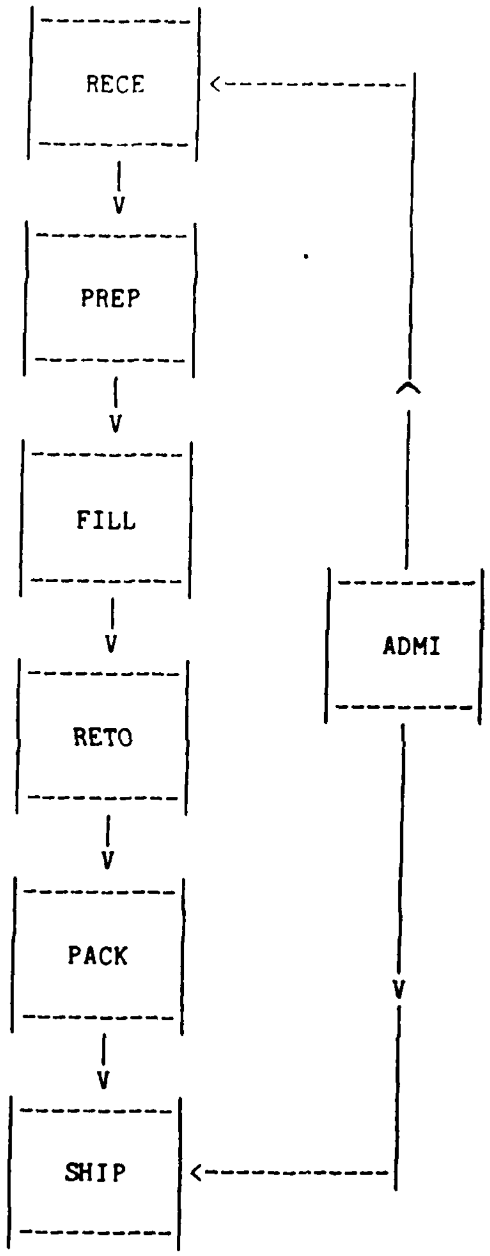

Figure 1 Activity relationship diagram

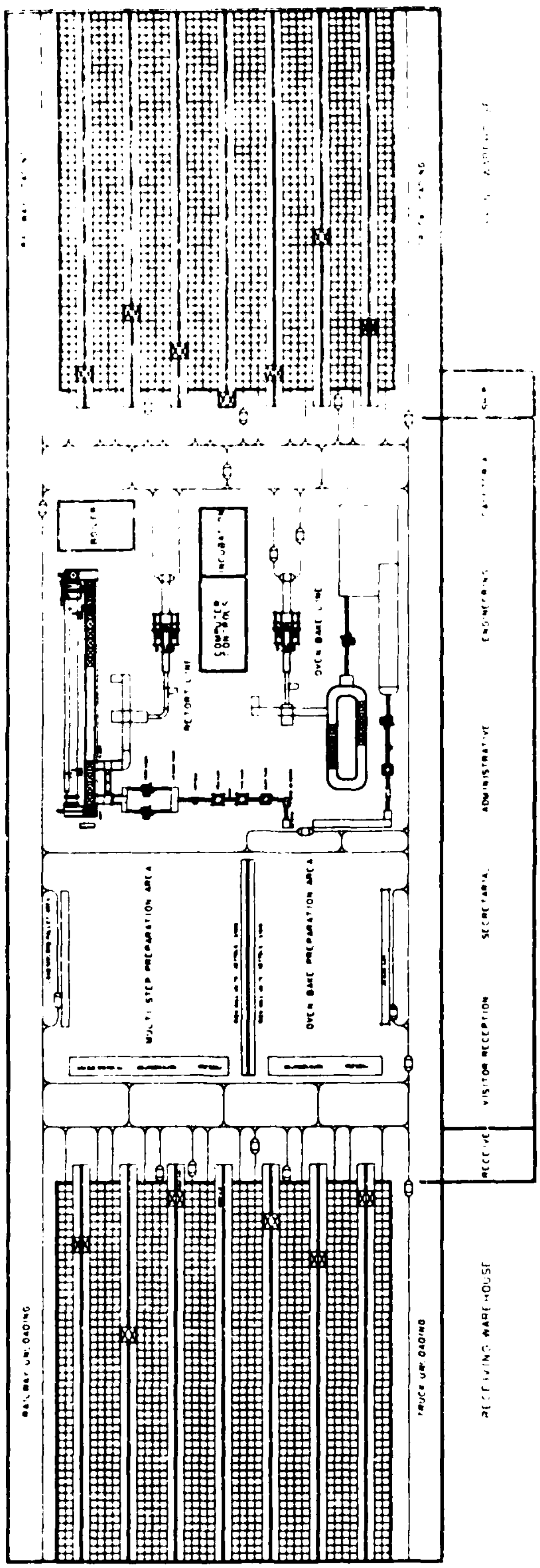

Figure 2 Schematic plant layout

C H A P T E R 3. Receiving Warehouse

A. Activity Description

The *Receiving Warehouse* will accommodate the reception of dry goods storage as well as frozen and refrigerated items, trays, lids, pallets, packaging materials and other commodities necessary in the manufacturing of the Tray Packs. As such, the major activities that must be incorporated into the *Receiving Warehouse* will necessarily include:

- o Loading docks/ Truck Turnaround/ Rail Linkage
- o Raw Material Storage
  - - Dry goods
  - - Freezer Storage
  - - Refrigerator Storage
- o Tray Pack Can storage
- o Tray Pack Lid storage
- o Fiberboard Box Storage
- o Empty Pallet Storage
- o Forklift Truck Storage

B. Activity Relationships

Most existing facilities the author visited in the initial *Producibility Engineering and Planning*(PEP) Project report did not have this clear separation from the Receiving and Shipping Warehouses and many circulation conflicts within the material handling system were evident, even though the low volume of Tray Packs at these facilities would seem to indicate that such separation was unnecessary. Given the potentially large volume of demand, this separation is felt to be essential.

The Automated Storage and Retrieval System (AS/RS) is designed to maximise the cubage of the Warehouse and utilise computer operations in the control of the picking and placing of raw materials. It is interconnected to the horizontal flow of goods via the conveyors and Automated Guided Vehicle System (AGVS).

The *Receiving Warehouse* is approximately 230 feet in length by 228 feet wide for a total square footage area of 52,440 square feet, including the loading and unloading docks. There are a total of 12,500 pallet loads in the current configuration. The number of pallet loads was based on the output volume of the Shipping Warehouse and a detailed argument is given in Chapter 8. Not only does the number of pallet loads reflect the ingredients for the Tray Pack menu items, this number reflects all the other items that could be stored in the Warehouse for the production of Tray Packs. These other items include the empty trays, lids, pallets, extra equipment, and supplies necessary for the general operation of the Tray Pack plant. See Figure 3 for a layout diagram of the *Receiving Warehouse*.

There are seven aisles in the AS/RS with the Freezer area in the central aisle and the two refrigeration areas encompassing it to maintain better climate control. The Freezer aisle is designed to provide an operating temperature of between $[-10°F \sim -12°F]$, while the Refrigeration aisles are designed to maintain a temperature of between $[30°F \sim 40°F]$.

Flanking the two refrigeration aisles are dry goods storage to complement and insulate the refrigerated items. This is a very compact arrangement and befits this type of automation.

Each pallet rack is capable of storing 9 racks each on its own level for a total height of 51.58 feet. With the roof truss, the overall height of the Warehouse is around 55 feet. See Figure 4 for a section through the Warehouse

The pallet racks are double–wide in order to maximise the density of storage. Alternatively, single wide pallet racks are often used, but to demonstrate the capabilities of this system, a double wide pallet rack operation was chosen. The throughput of each automated aisle is designed for a maximum of 15 pallets per hour. The maximum load for the robot cart operating down each aisle is designed to be 3500 lb, with a rectangular cube the most likely storage shape.

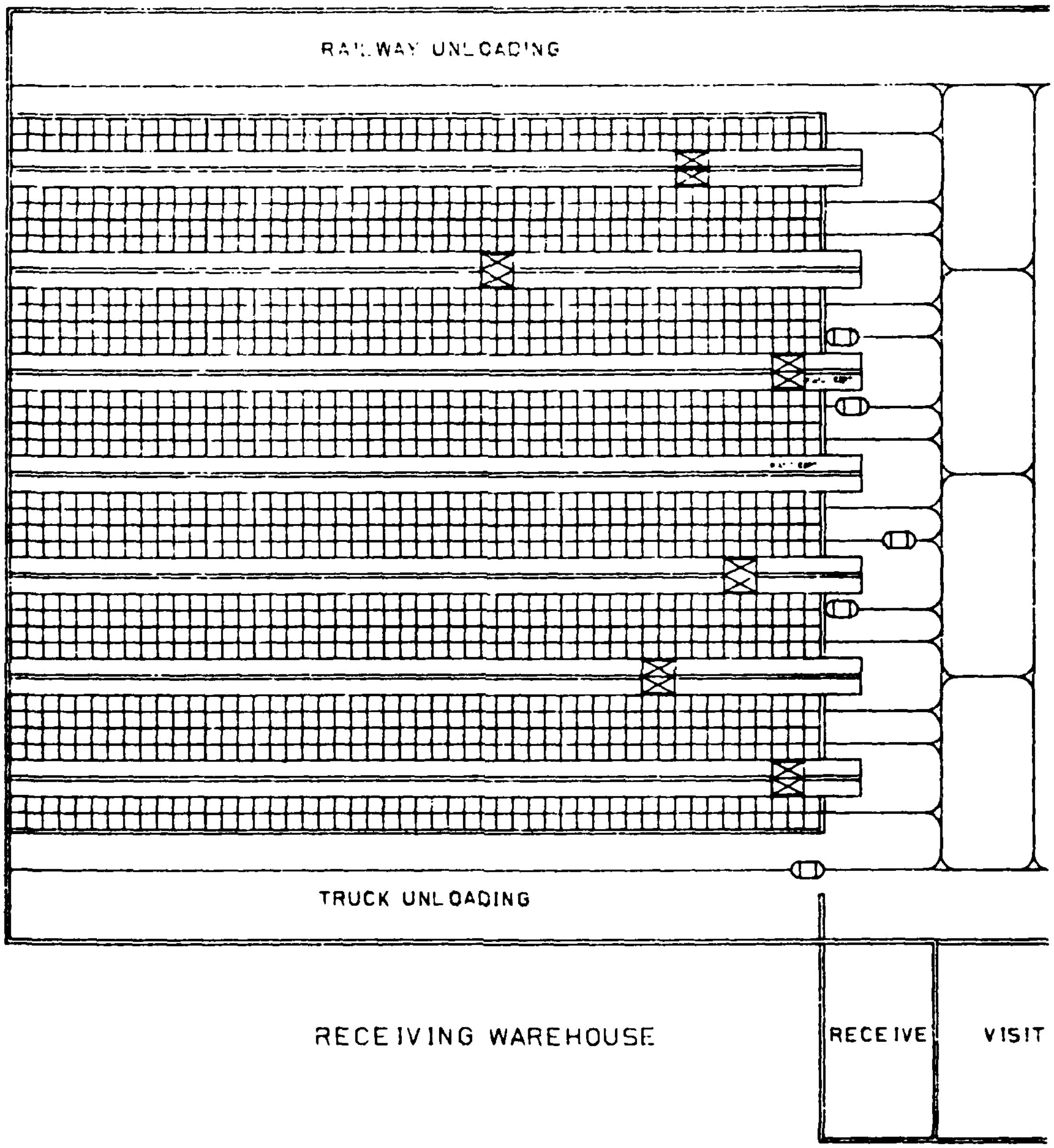

Figure 3. Receiving Warehouse Layout Diagram

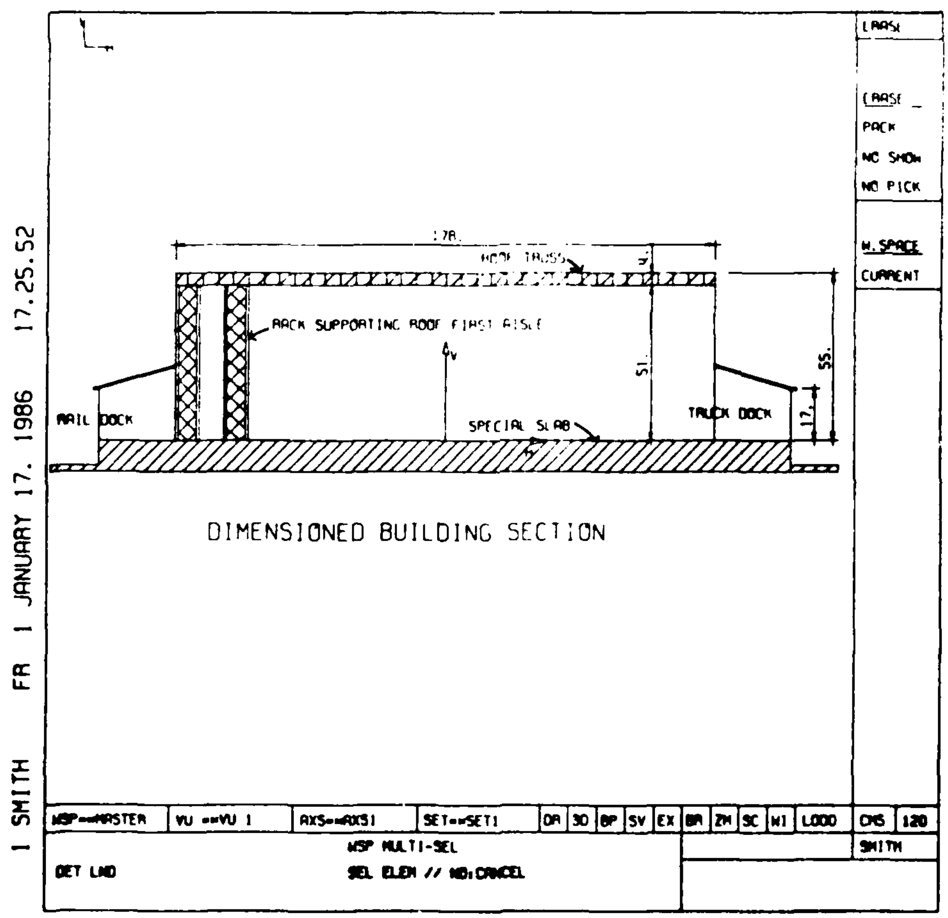

Figure 4 Section through receiving warehouse

The AS/RS and AGVS systems may be a rather expensive capital investment, so that one could make an argument for pallet racks and forklift trucks. Nevertheless, the tradeoff here is that the non-automated pallet rack system will require more square footage, more personnel to operate, and higher maintenance costs. To accommodate the same number of pallet loads within the *Receiving Warehouse* as is indicated in the drawings, a normal pallet rack and forklift truck system would require at least one-half more floor area. The area saving is explained in the area calculations within Chapter 8 on the discussion of the Shipping Warehouse. Also, the AS/RS and AGVS systems will allow the plant to operate 24 hours per day. In addition, the AS/RS reduces circulation inefficiencies and thus requires a smaller warehouse envelope. Finally, there are tax advantages that come with the AS/RS since it can be constructed as a separate building.

In the front of the Warehouse are the AGVS and conveyors which pickup and drop off the pallet loads. The AGVS vehicles are designed to operate in both directions to maximise flexibility in the delivery of materials. Figure 5 illustrates the relationship between the AGVS and the AS/RS. The AGVS is a key ingredient in the Material Handling System (MHS) of the plant. The AGVSs are designed to travel in both directions and move a pallet onto and off their loading/unloading beds to the various destinations throughout the plant. Certainly, forklift trucks may have to be used to supplement the AGVS system, yet, it is felt that the technology for controlling AGVS vehicles is such that the Tray Pack plant can be essentially designed around them. The AGVS vehicles and track interlink all areas of the plant. Appendix B illustrates some manufacturer's products for *these AS/RS and AGVS systems* which are becoming quite commonplace among food processing manufacturers.*

* I am indebted to Mr. William B. York of *Eaton-Kenway* who assisted with the inital layout and design of the Warehouse and the AGVS interface.

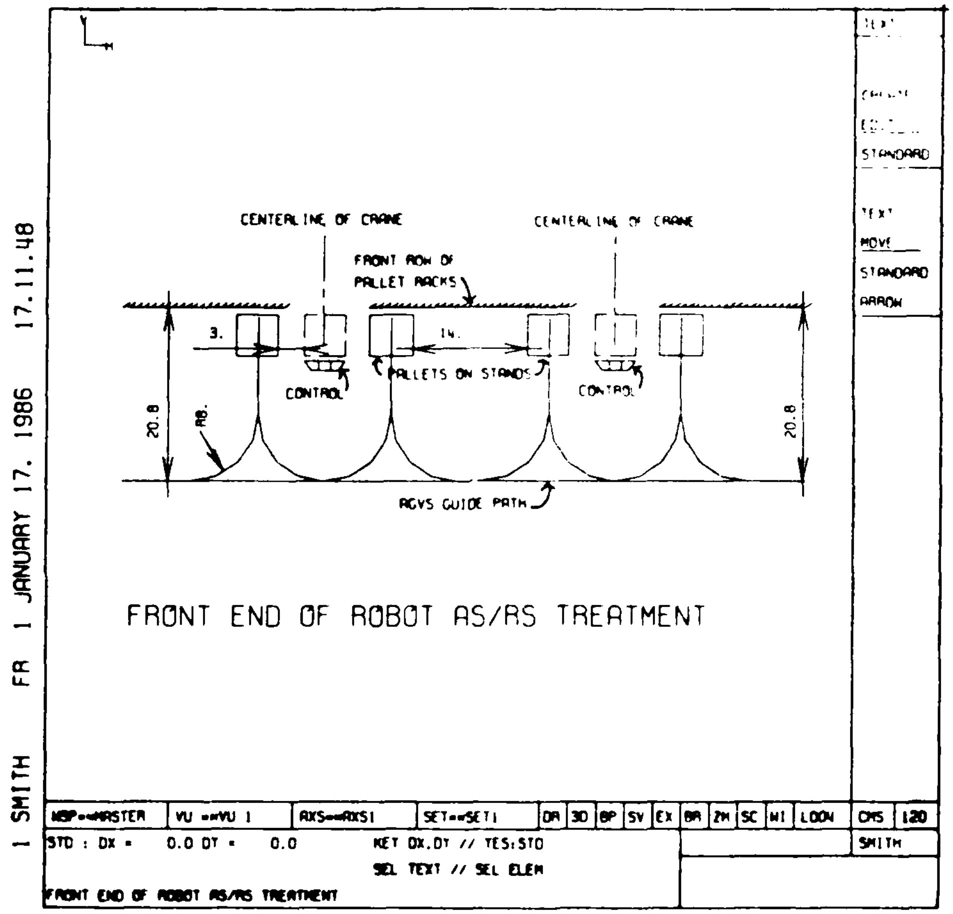

Figure 5 AS/RS and AGVS interface

CHAPTER 4. Preparation Area

A. Activity Description

The area items required in the *Preparation Area* include the following activities:

o Freezer Area (walk-in)
o Refrigerator Area (walk-in)
o Trimming and Dicing Rooms (large work tables)
o Cooking area (kettles/ ovens)
- Separate cooking area for retortable food items.
- Separate cooking area for oven-baked items.
o Mixing Vessels and other kitchen equipment such as tables, racks, and large carts.

B. Activity Relationships

The *Preparation Area* is designed to maintain the continuous flow of materials established for the plant operations. Refrigeration and Freezer areas are conveniently adjacent to the Warehouse and Can Assembly/Filling areas.

The *Preparation Area* is divided into two elements. The first is for the Oven Bake line preparation while the second is for the retortable items. Ovens, kettles, and other cooking equipment are combined into a utility wall so that power requirements for the two separate preparation areas are centralized, while the general work areas remain open and unobstructed. General cleanup of kettles, pots, and mixing vessels also links the two preparation elements.

The total square footage allocation for the *Preparation Area* is 23,546 square feet, with 13,908 square feet allocated to the Retortable item production and 9,638 square feet allocated for the Oven Bake production. The area is designed to maximize flexibility in the production of the different menu items so as little obstruction as possible is provided while traffic flows around the work areas. Figures 6,7 and 8 illustrate the Preparation Area and its components.

The AGVS system flows around the *Preparation Area* providing pallets of raw materials from the AS/RS system, which then can be moved to the Filling area via the AGVS or via pumpable systems where appropriate.

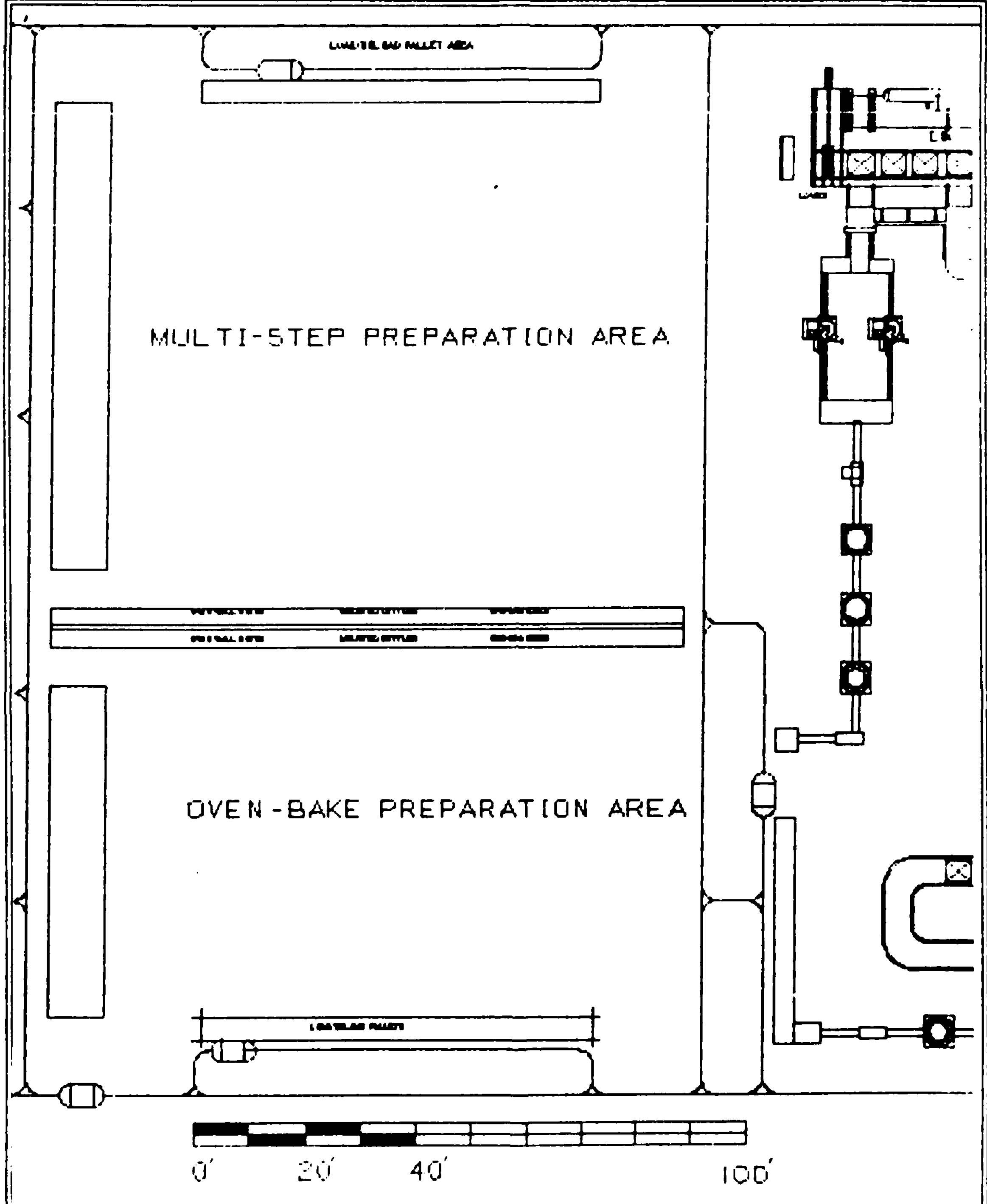

Figure 6 General layout of preparation area

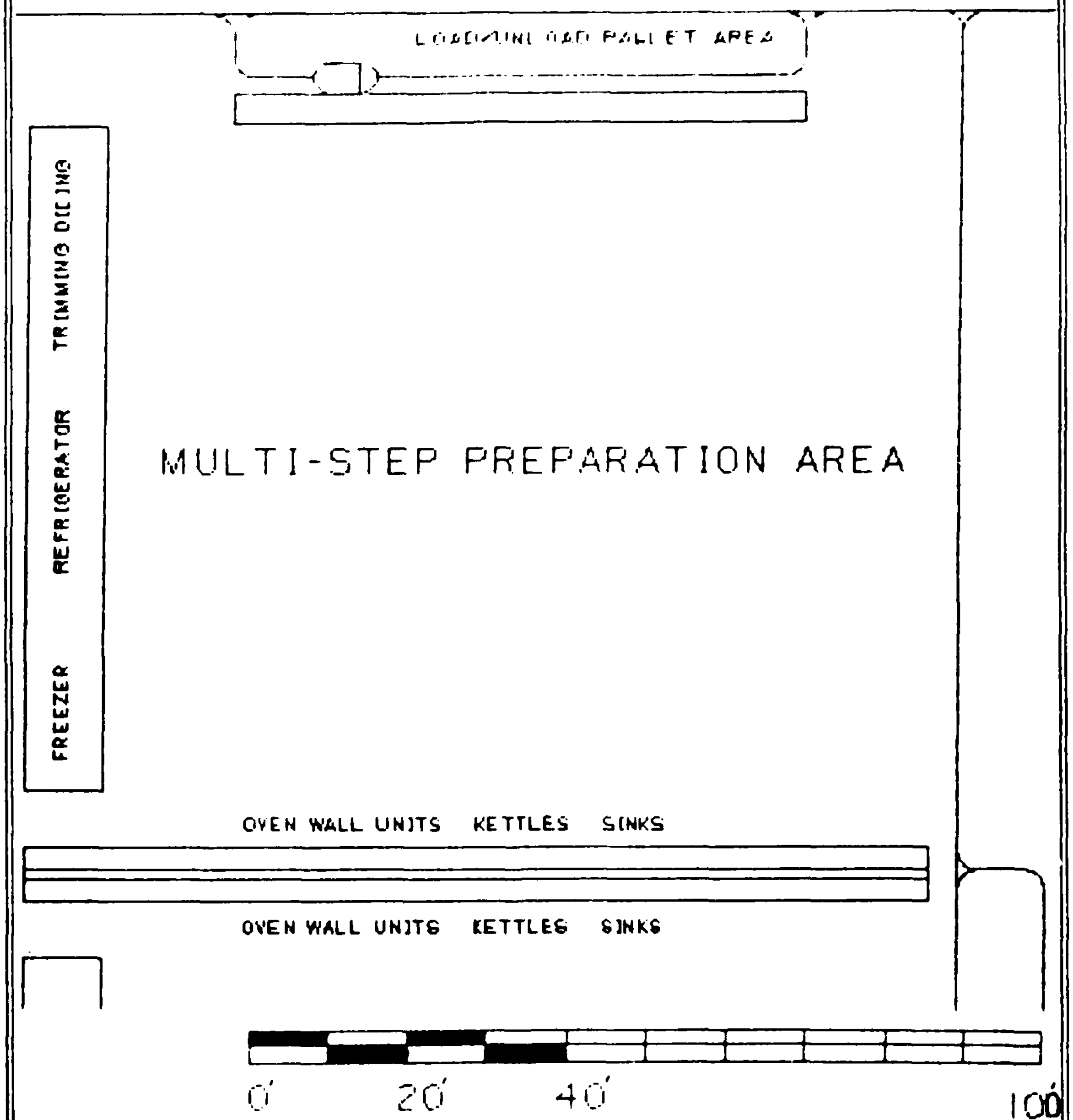

Figure 7 Retortable item preparation area

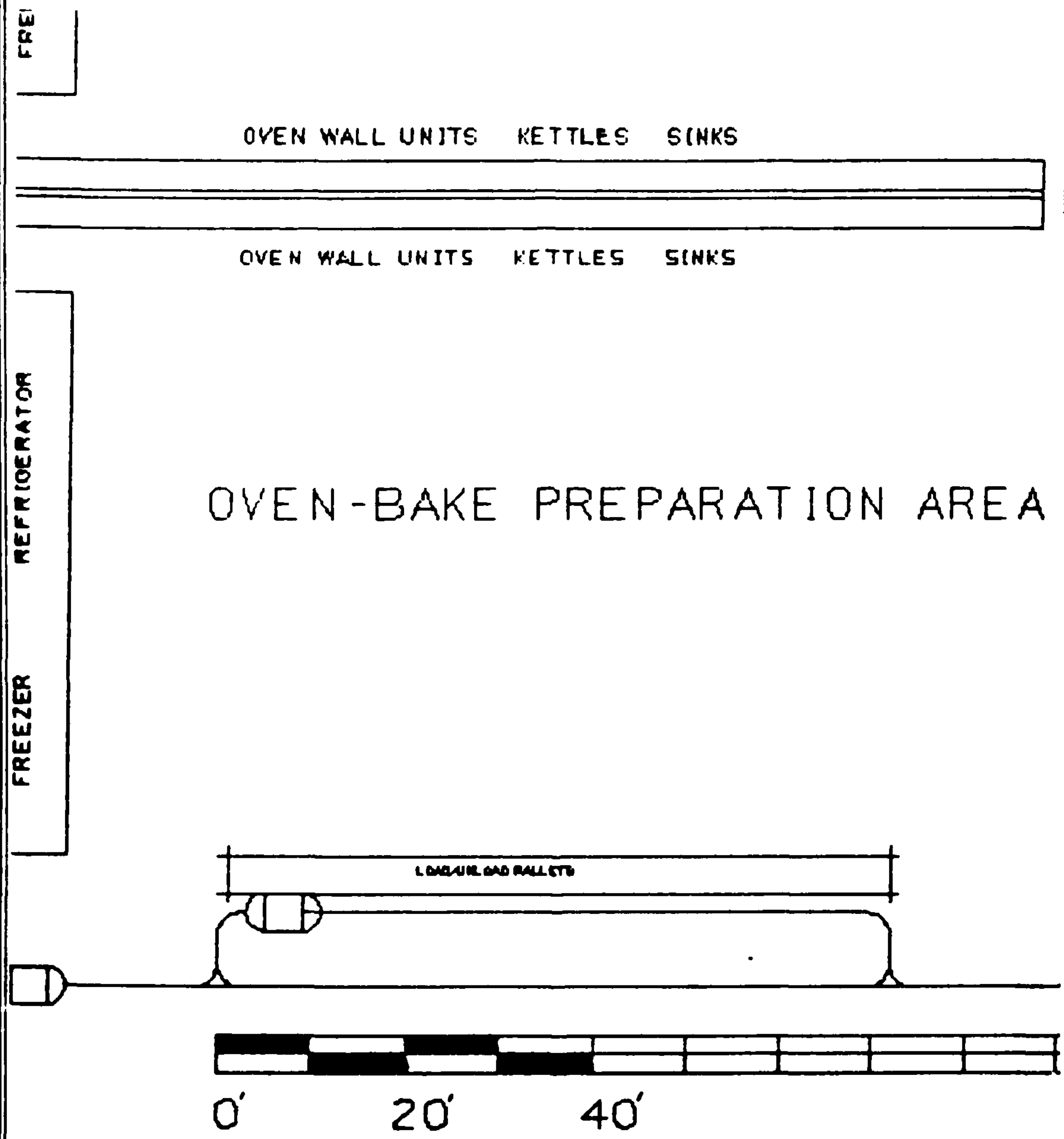

Figure 8 Oven bake preparation area

CHAPTER 5. Assembly Area

A. Activity Description

The *Assembly Area* constitutes the heart of the filling and closing operations of the Tray Packs manufacturing plant. All automated assembly of the contents of each can are to be carried out here. This area of the plant will be designed in much more detail than the other parts of the plant, since the current automated technologies of filling the Tray Packs are more critical at this stage of the Tray Pack manufacturing process.

The essential major activities included are the following:

- o Can and lid setup areas
- o Retort Filling Line
- o Oven Bake Line
- o Sterilization Loading/Unloading

B. Activity Relationships

This *Assembly Area* is the critical cost containment operation of the Tray Pack manufacturing process. Cans and lids travelling from the Warehouse join with the preparation of items and the line equipment. As mentioned previously, two types of high speed assembly lines are required for Tray Pack manufacturing operations. The Retort line which should operate at 40 cpm and the Oven Bake line which will operate at 20 cpm.

Let's discuss some of the detailed requirements for the Retort line, then the Oven Bake line. Some of the detailed activities which must occur for the Retortable line include:

Phase I. *General Hand Placement, One-Step and Two Step Filling Line:*

i) Can feeding mechanism

ii) Can washer

iii) Conveyor to Gravity (Shaker type) Volumetric filler for large and irregular menu items.

iv) Piston filler for certain viscous items.

v) Liquid Filler for less-viscous items.

vi) Automatic Check-Weigher and Reject machine.

vii) Vertical lid feeder (500-600 lids).

viii) Y-channel or similiar distribution conveyor to transfer cans to available seamers.

Phase II. *Closing Equipment*

i) Two automatic seamer(s), Yaguchi or equal.

ii) Can washer at outfeed of each seamer

iii) Conveyor to trolley loading equipment

Phase III. *Trolley Loading Equipment:*

i) Accumulation Table and Conveyor to Steriliser

ii) Automated Loader/Unloader for Steriliser

In general, it is felt that the conveyor for the Retortable line should be a 16 inch wide powered conveyor that originates from the can washing area and interconnects all the filling machinery all the

way to the accumulation table for eventual loading of the Tray Packs onto the UFS trolley cars. Part of the conveyor may be magnetised upon emergence from the Lid-Feeder/Crimping machine as one way to keep the lids on the Tray Packs to avoid the sloshing and spillage problems as the trays move down the line.

The working height of the first stage of the line should be 36 inches high for conveniently filling the cans either manually or automatically. The working height of the Yaguchi is 1143 mm (approximately 45 in) so that the Yaguchi seamers *ideally* need to be recessed in the floor so as to maintain a uniform working height of 36 inches.

In designing the line layout, it was important to keep track of the following design variables:

1. Conveyor line speed and Machine Operating speeds
2. Finite Buffers in front of the work stations
3. Placement of work stations(machines)
4. Conveyor topology

What basically exists in the assembly line is a series of work stations connected together where queuing of the cans occurs as they travel the length of the assembly line because of the different machine and conveyor speeds, finite buffers, and throughput requirements. Mathematically this is called a queuing network, where the cans receive service along the line at the various work stations as they are filled. By modelling the filling line as a queueing network, engineers can vary the above design variables to see what parameter settings allow them to achieve the design line throughput of 40 cans/minute (cpm). The buffer sizes between machines which were set at a minimum of *seven* feet and were verified with the use of a queuing network model. In other situations where the throughput would not have to be as high as 40 cpm then different buffer sizes would be appropriate. In Appendix C, a SIMAN[3] simulation program, both the model frame and the experimental frame are included which was use to simulate the filling line to verify the line rate of 40cpm and buffer sizes of 7ft.

Some of the detailed activities which must occur for the Oven Bake line include:

Phase I. ***Oven Bake Filling:***

i) Can feeding and washing mechanism

ii) Automatic parchment placement

iii) Piston Filler with overhead injection mixer.

iv) Automatic Check-Weigher and Reject machine

v) Horizontal/Vertical lid feeder (200-300 lids) conveyor to transfer cans to available seamers.

vi) One automatic crimper, modified Yaguchi or equal.

Phase II. ***Baking and Cooling:***

vii) Oven

viii) Cooler

Phase III. ***Closing, Cooling and Loading:***

ix) Closing machine at outfeed of cooling area.

x) Accumulation Table and loader onto Drying Racks with automated trolleys.

xi) Unloading conveyor to packaging area.

C. Activity Relationship Diagram

Figures 9 to 20 illustrate the general Retort filling line area and its related work areas.

The Filling line for the retortable items is basically designed in three stages. The *first* stage is the Filling process where the cans are washed, filled, and weighed. The *second* stage of the process is where the lids on the cans are crimped or placed,and the cans are closed. Finally, in the *third* stage the cans are washed, accumulated, then shunted to the loading conveyors for sterilization.

In what follows, detailed drawings of many of the equipment items and their location relative to each other along the line are presented. The order of presentation roughly follows the actual line layout.

It should be pointed out that there are some new machines that need to be designed for this process. These include the *Gravity Filler* for the difficult items that are normally hand-placed within the trays, the *Lid Placement and Crimping Machine,* and the *Oven Bake Drying Racks and Trolley System.*

The *Gravity Filler* is designed as a rotary machine with 12 inch diameter shunts (or cones) which would place by gravity(or shake) the food items into the cans. Alternatively, this could be termed a *Shaker Filler.*

The *Lid Placement and Crimping* device would automatically place and either crimp the lids or magnetically place the lids on the tray as they move through the machine. Crimping or magnetically placing the lids is critical to minimizing sloshing and spillage of the tray contents. It would accommodate a minimum of 500-600 tray lids and since the throughput of the line at 40 cpm, it will have a maximum of 2400 cph. Careful design of this machine is important so that the next stage of the filling process, the closing of the cans proceeds without machine breakdown or loss of the contents of the can.

What is indicated here are rough design ideas of how these machines would be placed in the Filling line process and only the barest details of their actual design. Companies that would most likely carry out the final design process for these new machines are listed in the Appendices.

The design of the Oven Bake line is similiar to the line layout of Sterling Bakery in San Antonio, Texas since they have been the largest supplier of bakery items of Tray Packs. There are some differences however, mainly in the way the Tray Packs are accumulated after the cooling process and finally packaged. A device that needs to be designed is the *Automated Trolley Drying Racks* as indicated in Figure 20. Since the Tray Packs need to cool for about 1 hour after coming from the oven, a holding device is necessary before the cans are finally boxed, labelled, and palletised. This device is patterned after the automated accumulation and loading mechanism of the FMC UFS Sterilizer (see next Chapter).

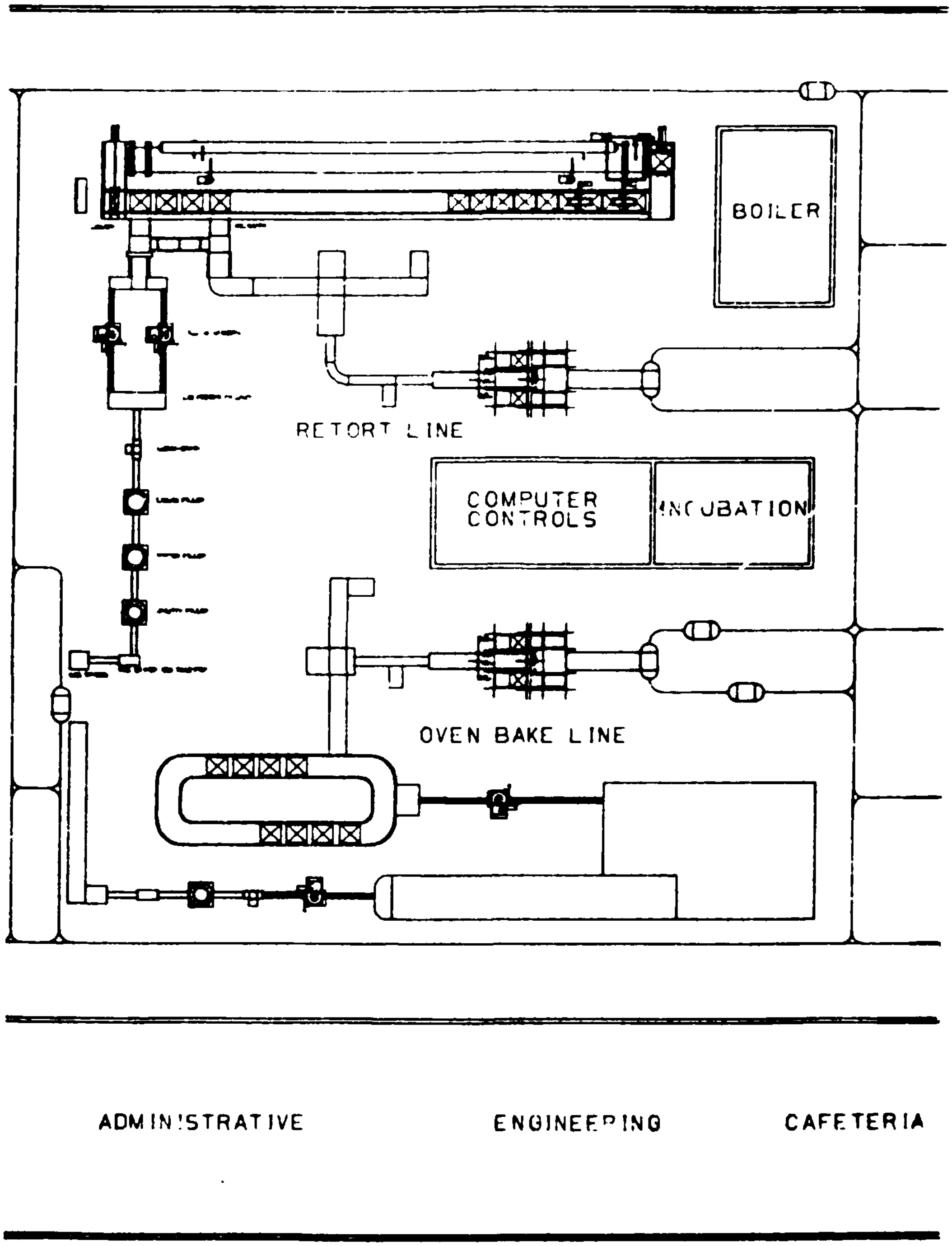

Figure 9 General filling operations

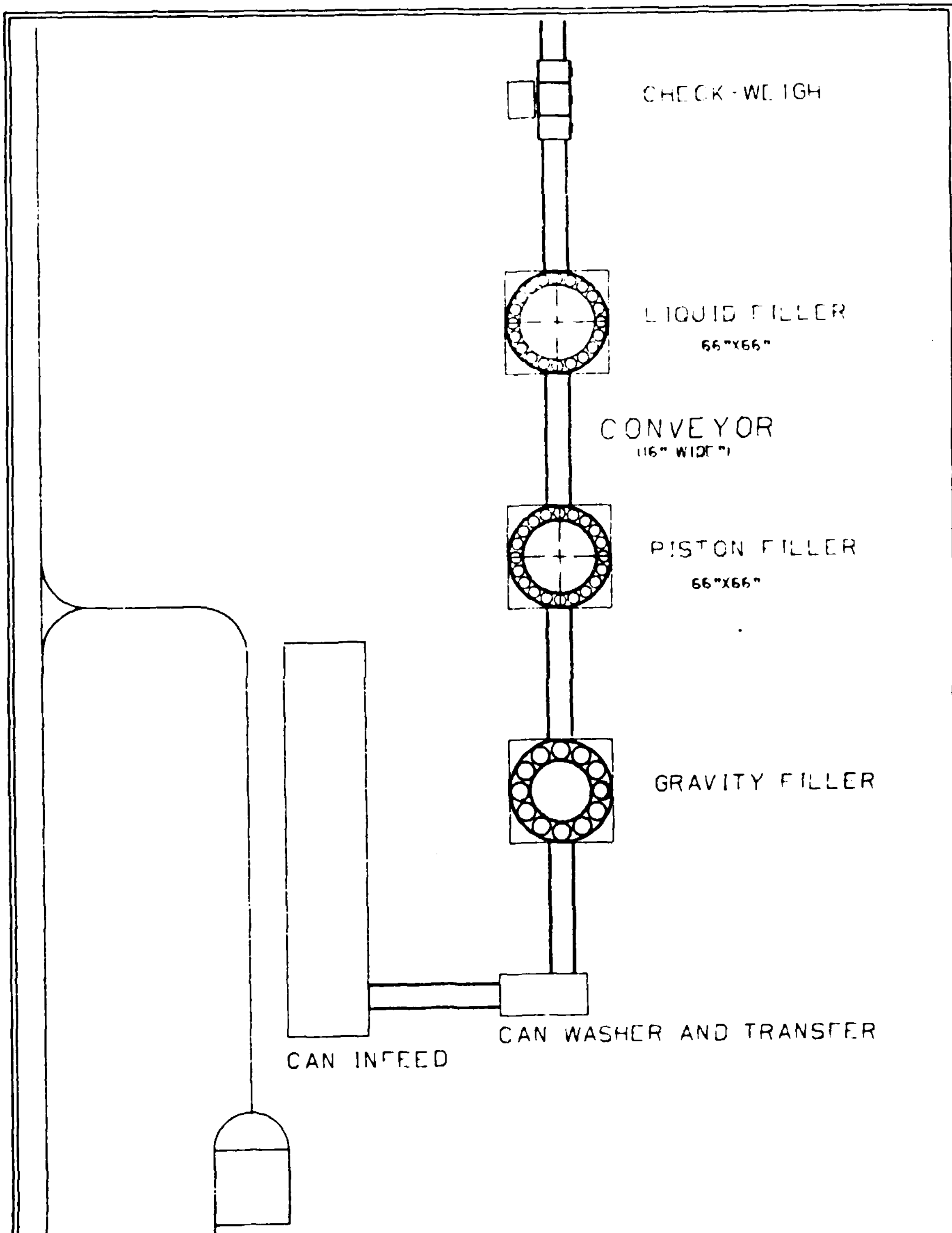

Figure 10 First stage assembly filling line

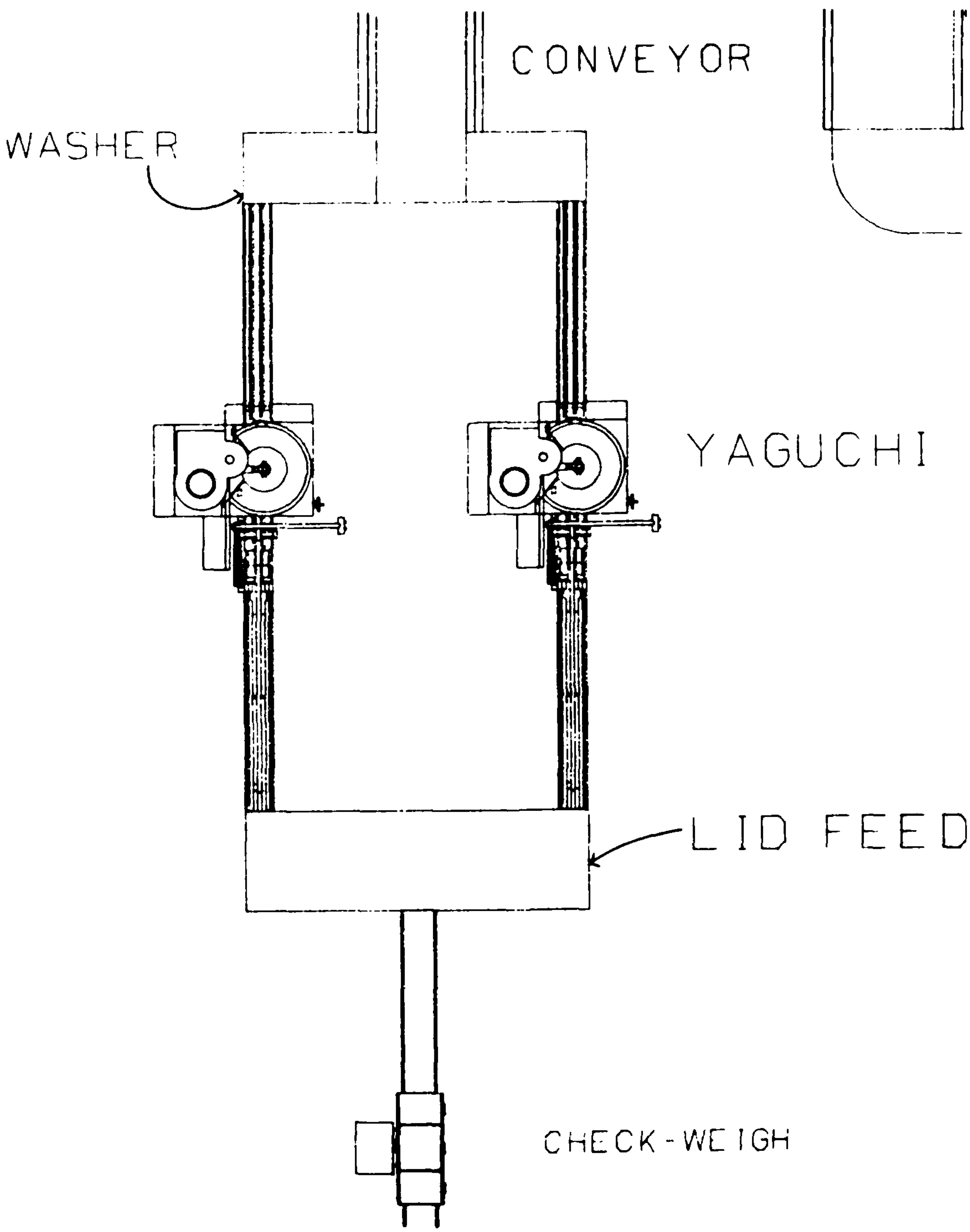

Figure 11 Second stage assembly filling line

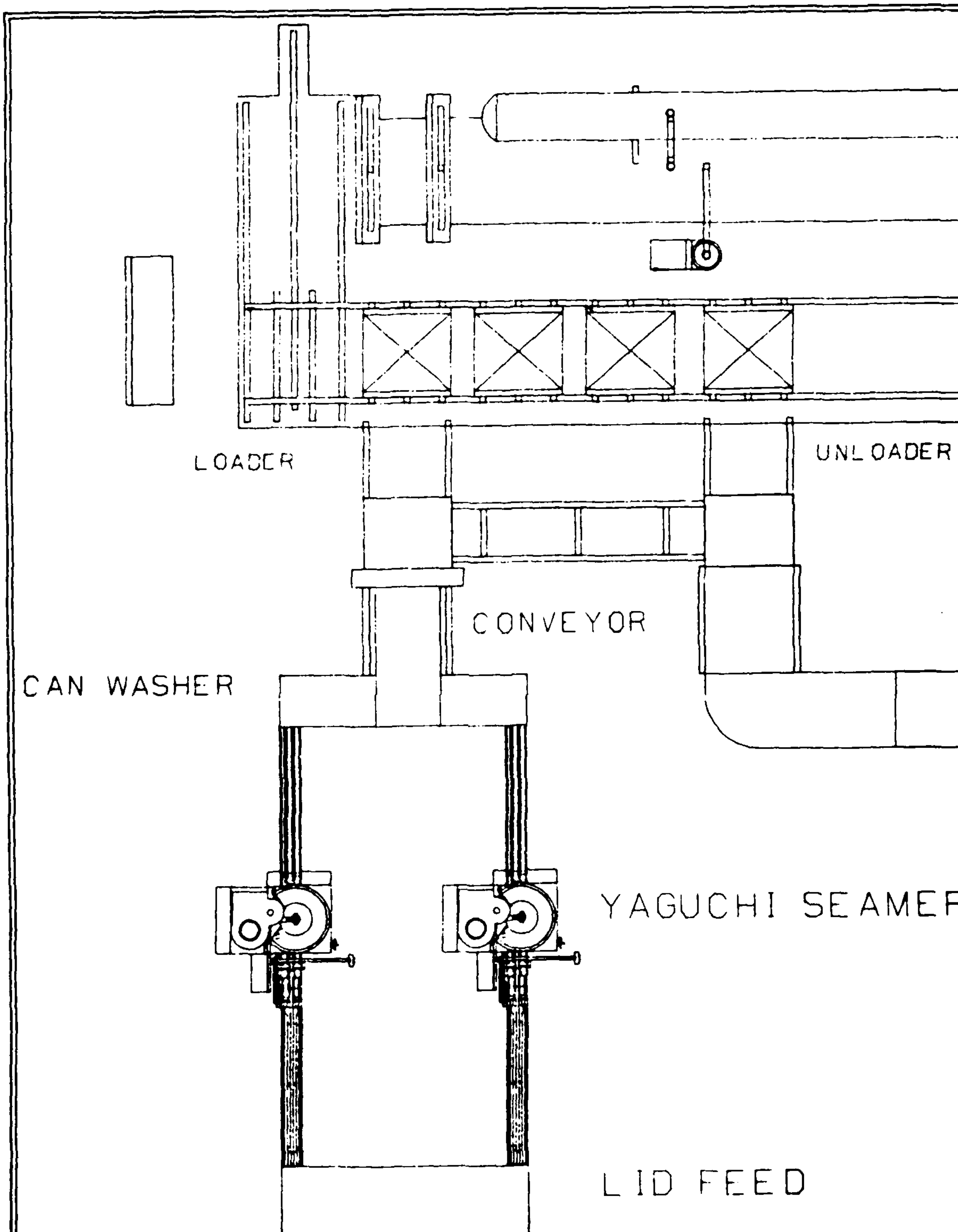

Figure 12 Second & third stage assembly filling line

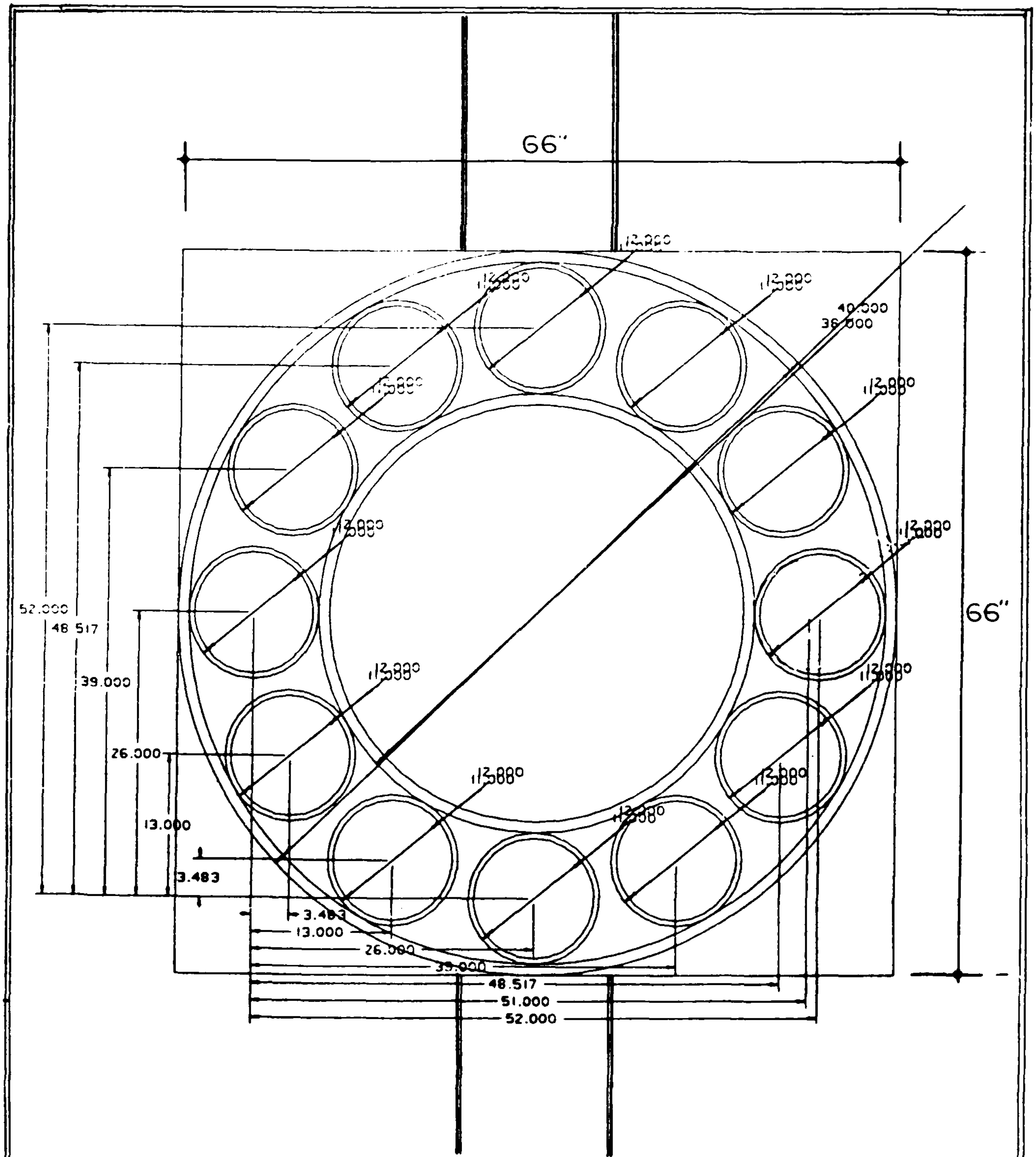

Figure 13 Gravity filler

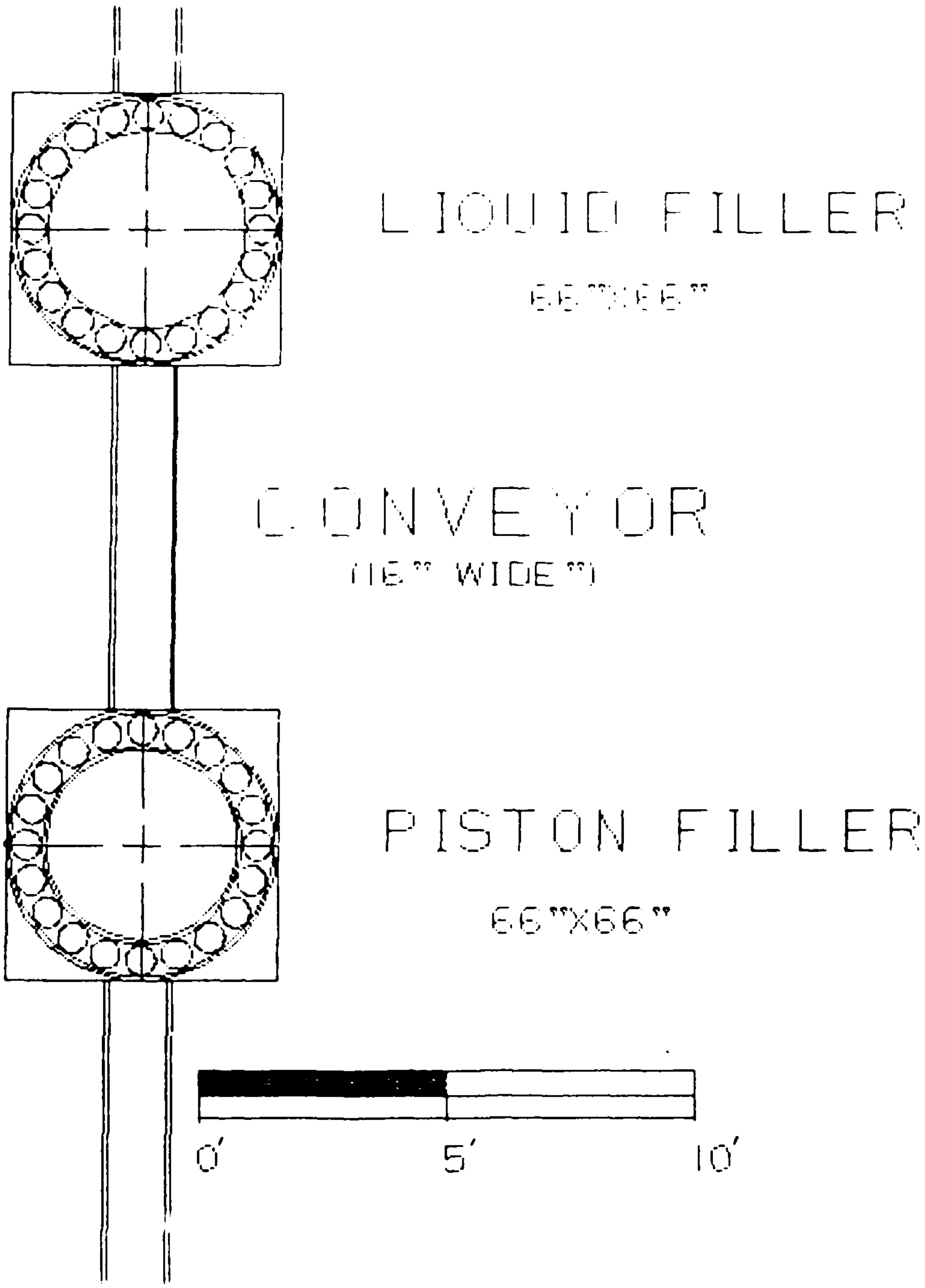

Figure 14 Piston and liquid fillers

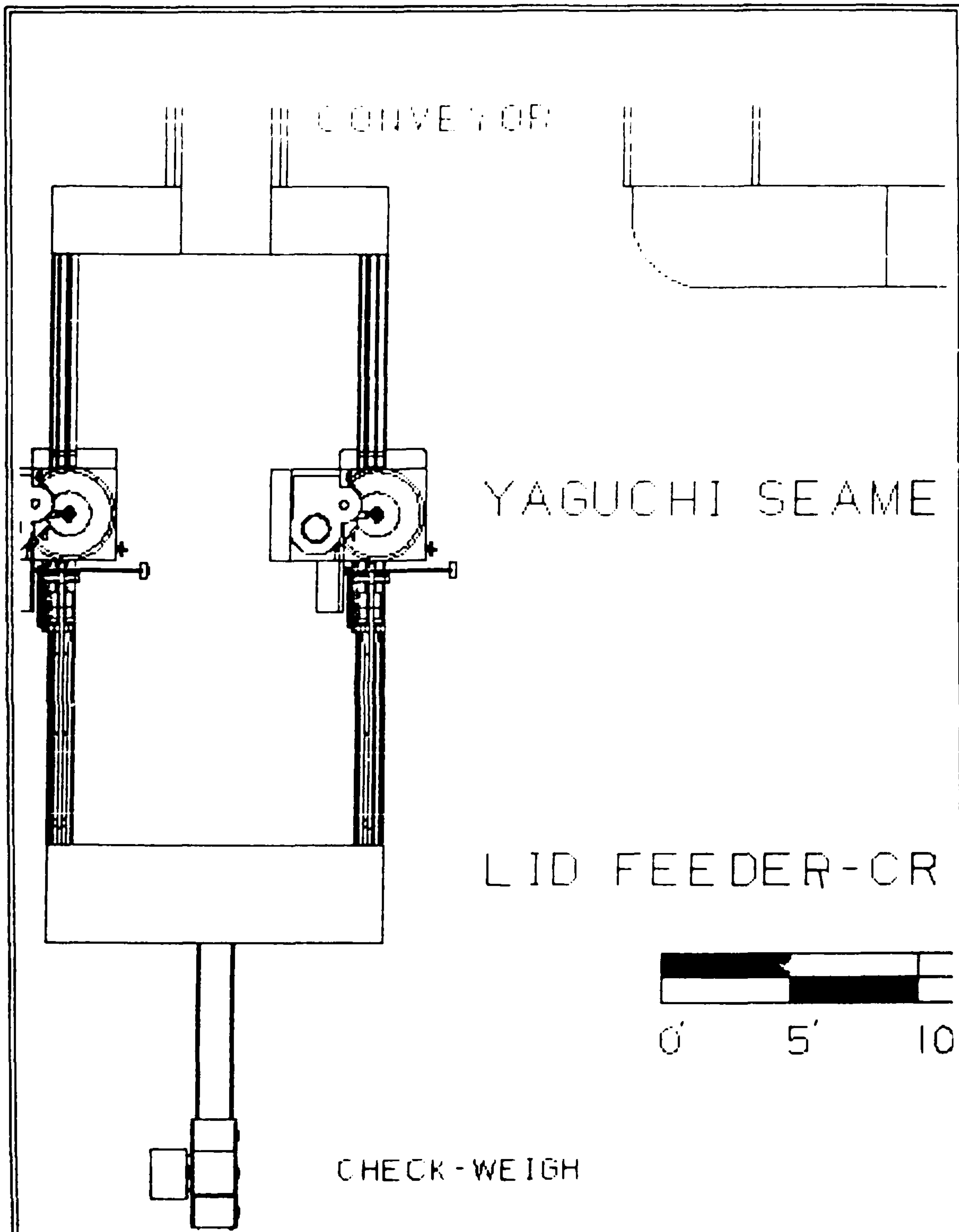

Figure 15 Lid placement and crimper

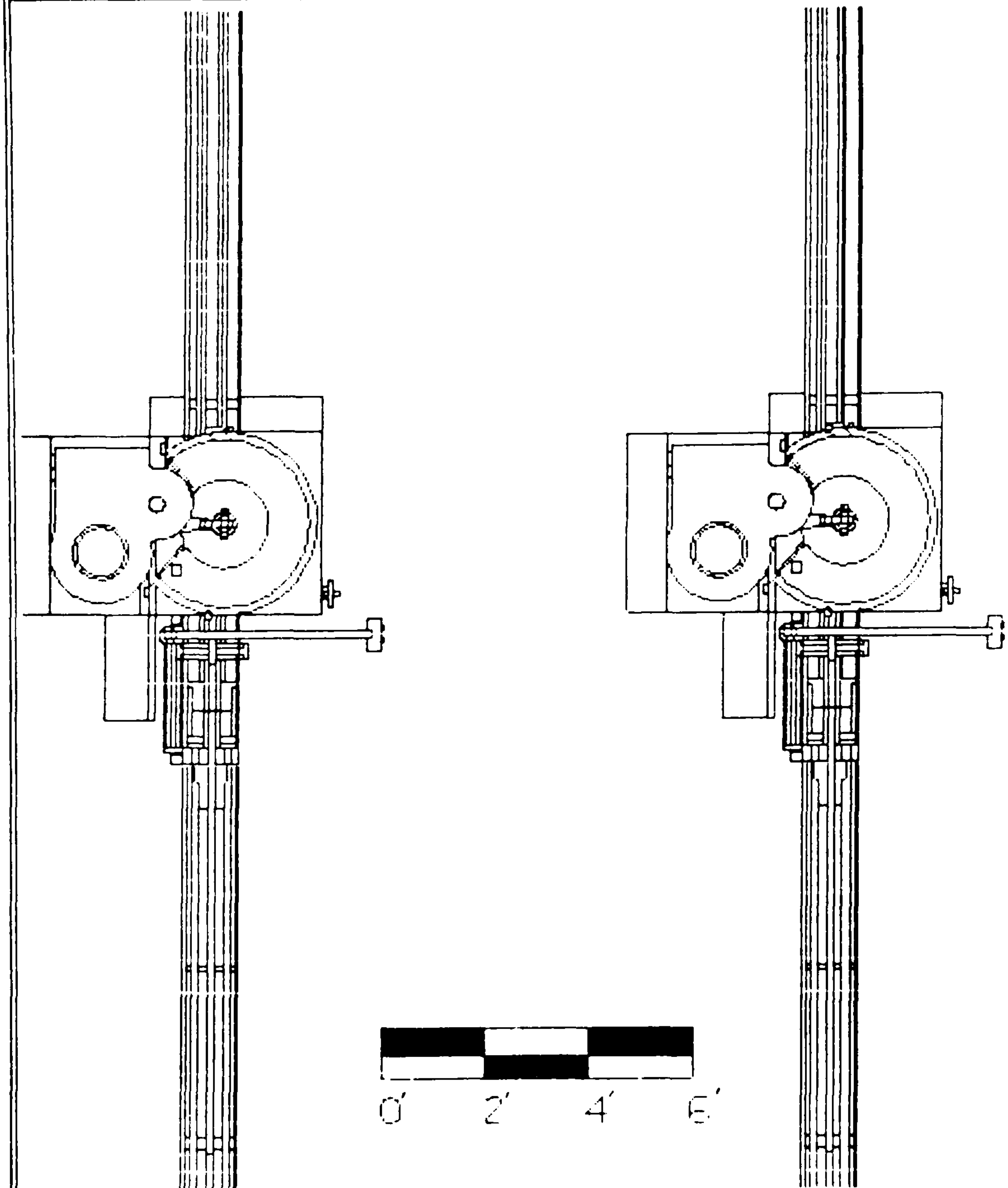

Figure 16 Yaguchi layouts

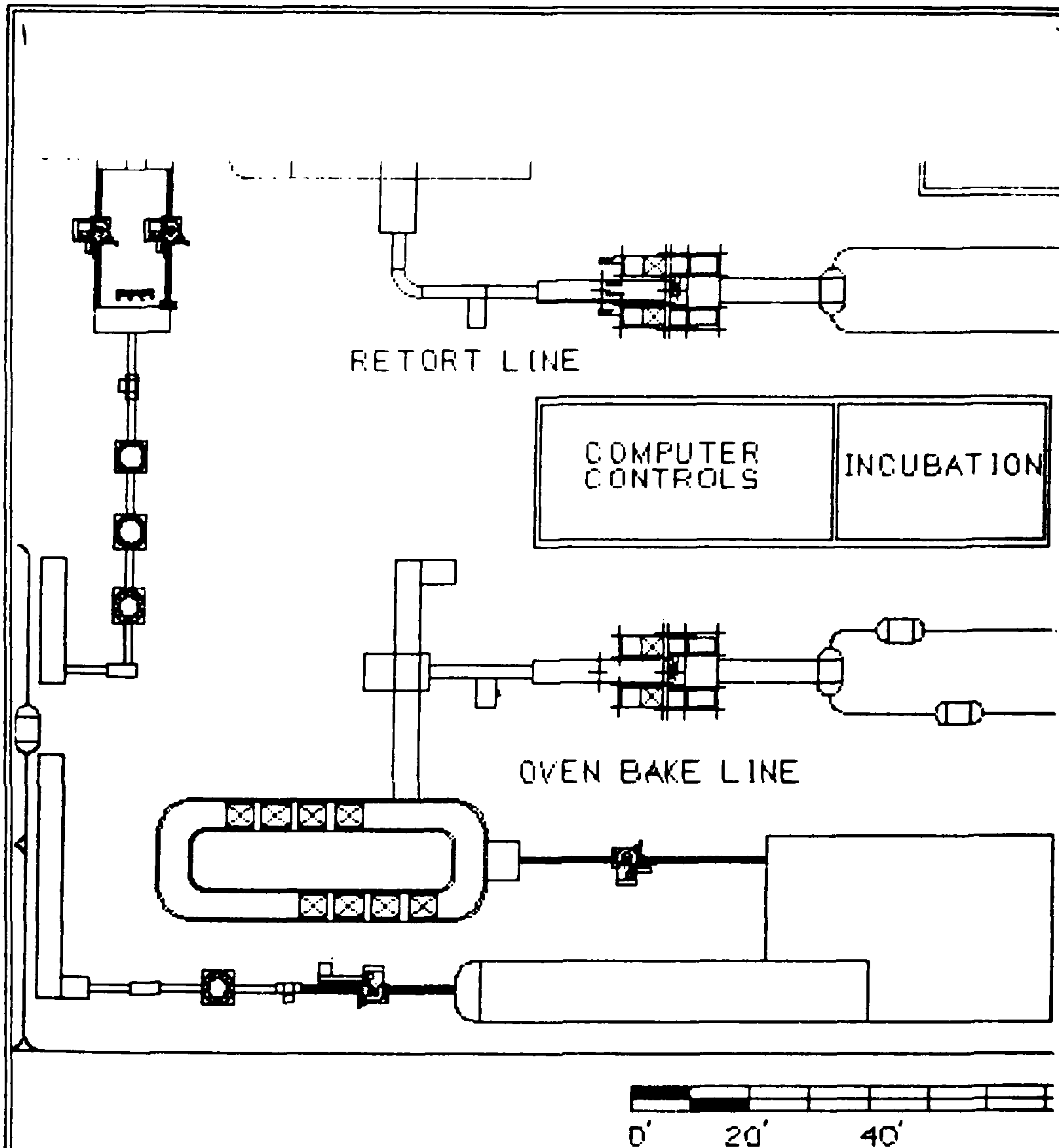

Figure 17 Oven bake line layout

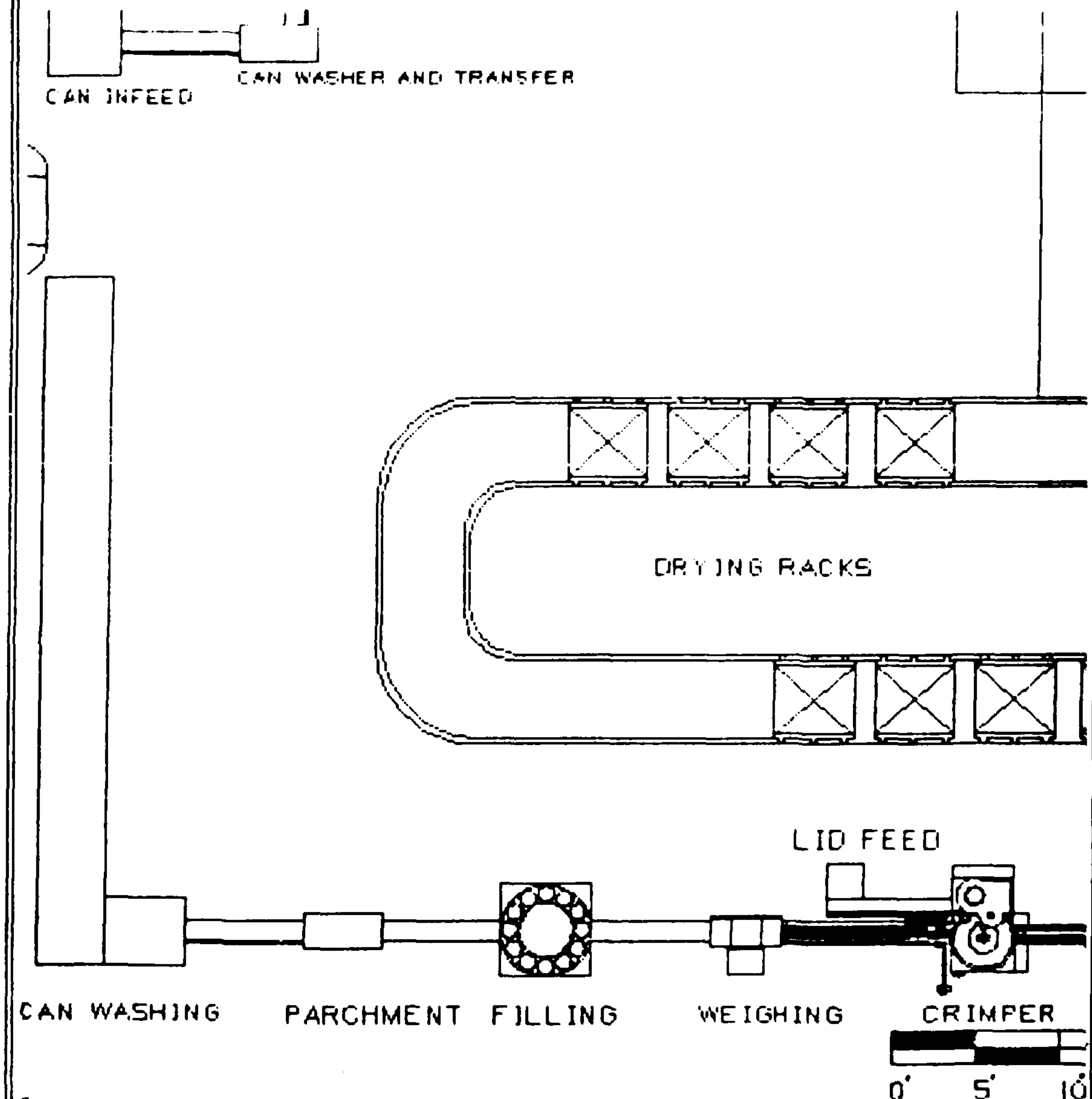

Figure 18 Oven bake filling operations

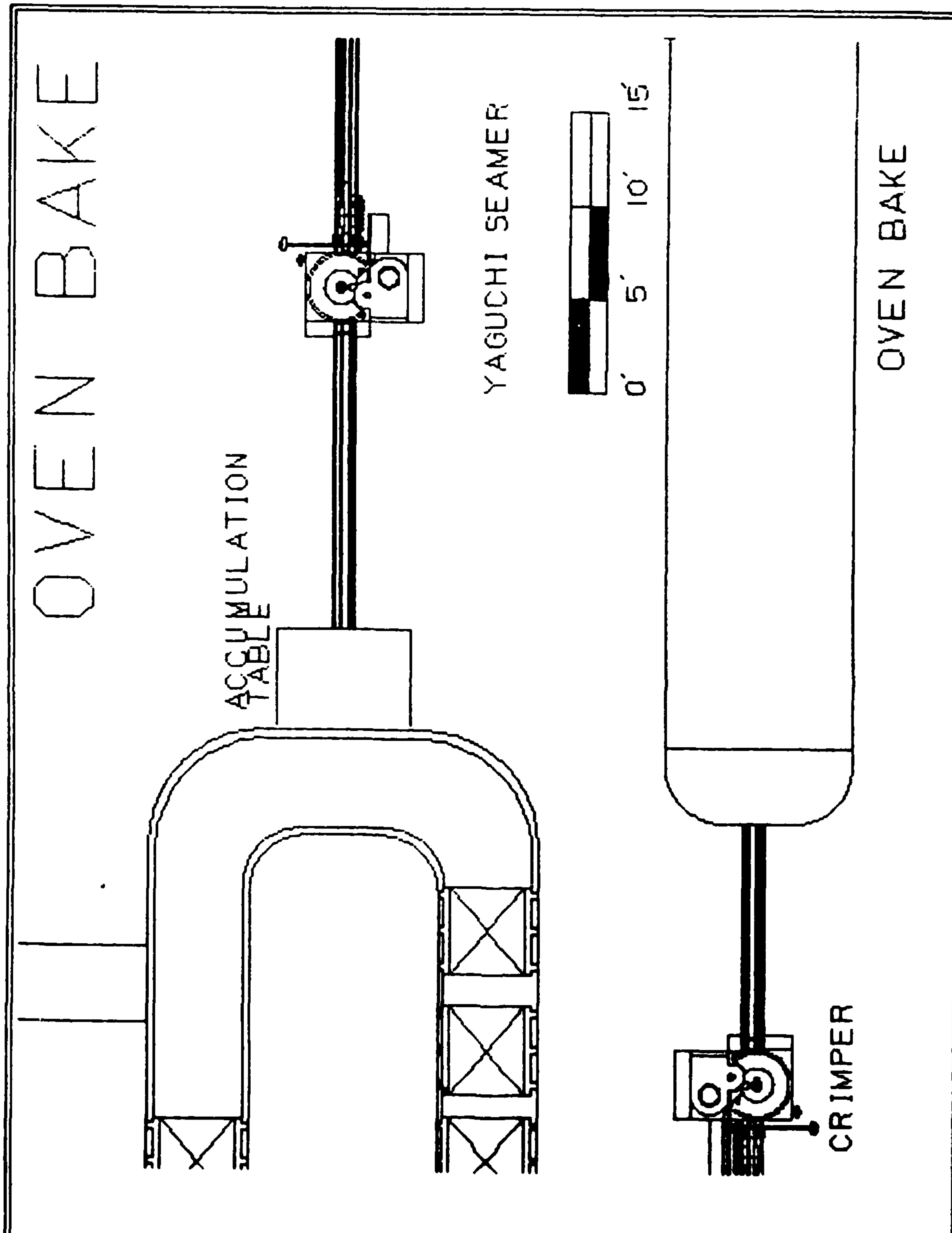

Figure 19 Oven bake closing operations

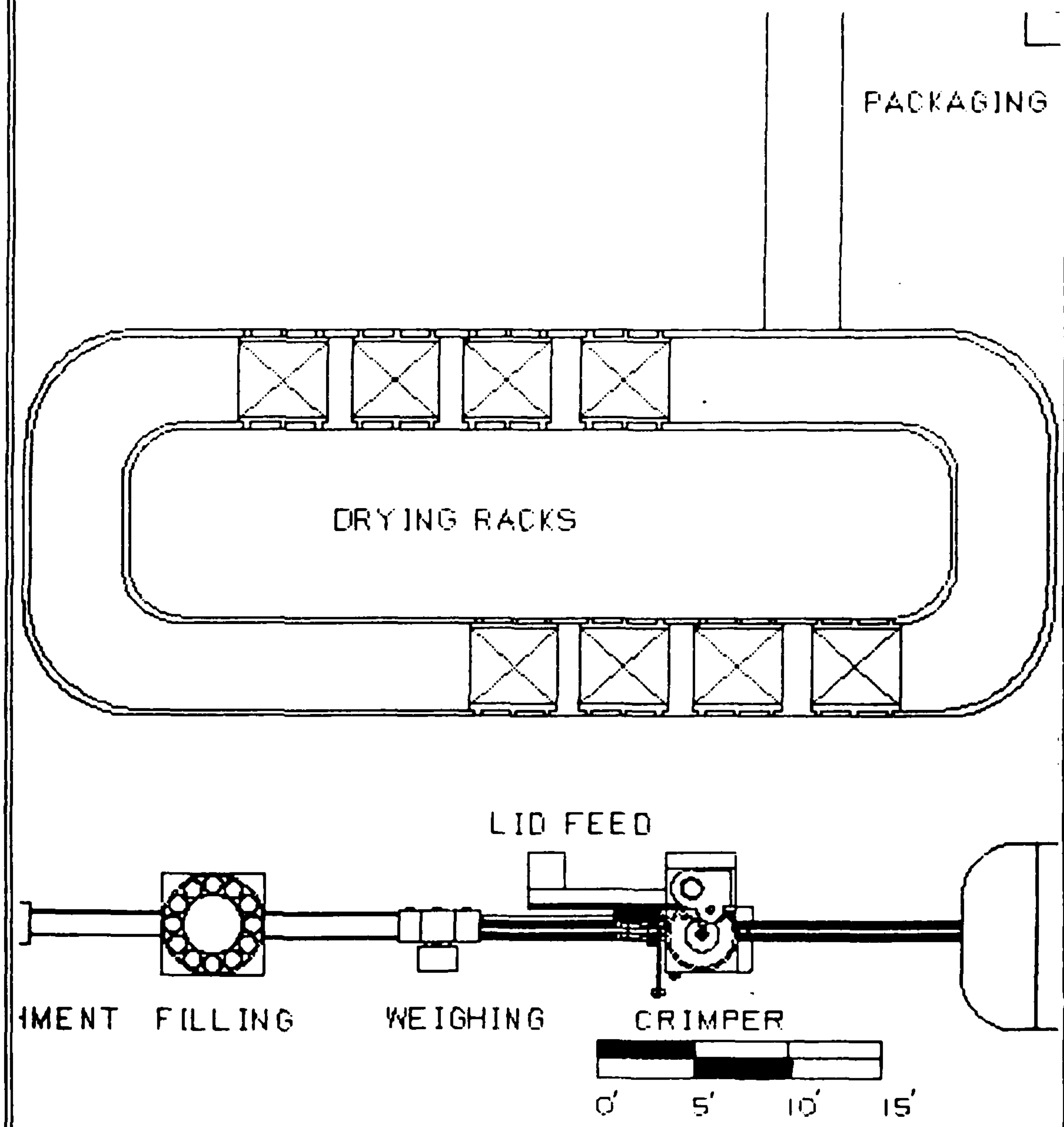

Figure 20 Oven trolley drying racks

CHAPTER 6. Sterilisation Area

A. Activity Description

The *Sterilisation Area* houses the retorting equipment and boiler for accommodating the assembled Tray Packs during sterilisation. The *Sterilisation Area* is designed around the Food Machinery Corporation(FMC) retort, the Universal Food Steriliser(UFS) with its trolley system for handling Tray Packs, the automated loading and unloading system, and a computer control system.

The detailed activities included in the area are the following:

- o Loading/Unloading from Filling lines
- o UFS Retort (or equal)
- o Boiler Room.

B. Activity Relationships

The sterilisation process becomes one of the most crucial design determinants in achieving the desired throughputs of 40 cpm and eventual production volume for the plant. Even with the UFS Continuous steriliser, there are capacity limitations which must be addressed.

In the assumptions required for sizing the UFS, it can be shown that the trolleys circulating through the UFS are only capable of holding 144 cans. This is due to the size of the Tray Packs and the automated loading/unloading process.

If automated loading/unloading is not required, then larger capacities on the trolleys are possible. However, this requires hand-placement of the trays after the closing operation, and this is not practical in a high-speed manufacturing operation.

In addition, if one compares the UFS with FMC's batch retorts, the *Continuous Food Sterilizer (CFS) Model Number 24,* which is capable of holding 4 trolleys of 144 cans each, one can get a better idea of the capability of the UFS as opposed to traditional batch retorts. This *CFS No. 24* batch retort has a larger capacity than most other batch retorts, 576 Tray Packs, as opposed to 256 Tray Packs which is common with *Rotomat* and *LeGarde.* In the comparison table which follows, one should multiply by a factor of *two* in order to get the equivalent number of batch retorts, e.g., *Rotomat or Legarde* that would be necessary to accommodate the throughput of the plant.

The following data in Table 2 were generated by a representative from FMC.

Table 2. Sterilisation Process Specifications

Cans per Minute (cpm)	*Cook Time*	*Cooling Time*	*Trolleys*	*Overall Length*	*Loaders Unloaders*	CFS *Equivalents*
20	50	30	9	59	1 each	4 CFS
20	80	30	14	79	1 each	6 CFS
40	50	30	18	95	1 each	9 CFS
40	80	30	27	131	1 each	11 CFS
60	50	30	25	123	2 each	11 CFS
60	80	30	38	175	2 each	16 CFS

For cook times ranging between 50 and 80 minutes, the 60 cpm throughput rate is really not feasible for *one* UFS, rather *two* UFS sterilisers would be required for the Tray Pack facility. *Two* UFS sterilizers may be justifiable in a facility that is producing more than 17 million trays/year, but this study will not consider such a possibility.

This limitation of the UFS Steriliser is quite important to the layout of the plant as well as future studies. The reason the UFS is not capable is due to its overall length and number of cars required. Beyond 30 trolley cars, the representative from FMC believes that the UFS becomes inefficient both

from a mechanical engineering (heat tranfer) point of view and from an engineering economy point of view.

It can also be argued that below 4–5 *CFS* batch sterilizers or (8–10 *Rotomat* equivalents), one UFS is not cost effective. Thus, unless the Filling line operates at 20 cpm for an 80 minute cook time, one UFS is not justifiable. These lower bounds of 20 cpm and 80 minute cook times are really quite conservative since many of the products are likely to require at least 80 minute cook times. This is basically a cost-effectiveness argument since each *CFS 24* costs around $225,000 without any automated loading and unloading equipment and material handling system while the equivalent UFS costs around $1.2 million. For *five* CFS equivalents, the automated loading/unloading as well as the costs of water and energy make the UFS more cost-effective.

Also, the UFS is a *dedicated* line system, so that multiple products cannot be run on the separate lines feeding the UFS. Rather, whatever assembly lines feed the UFS, they should be a single product. Thus, in order to schedule production on a UFS, the production periods must be scheduled for one product, shut down, then set up for another product, otherwise, inefficiencies will result. Finally, multiple products would require some area for queuing of the trays, and this may not be suitable from a Food Science viewpoint since critical gases may build up in the tray before it is sterilized.

For the particular configuration shown in Figures 21 through 24, the following detailed specifications regarding the design and operations of the system are provided.

The utility requirements for the UFS are as given in Table 3:[4]

TABLE 3. Utility Requirements for Universal Food Sterilizer

Steam: Approximately 0.15 ~ 0.25 Kg steam/Kg Product

Water: Approximately 2.5 ~ 3.4 l water/Kg product ($.3 \sim .4 gal/lb$)

Air @$4.22 Kg/cm^2 (60 psi)$

A. Approximately $2.12 m^3/min. \sim 5.66 m^3/min$ ($75 \sim 200 CFM$)

Electrical

	KW	*HP*
Cars between the locks - (per car)	3.7	5.0
Pump for hot well	5.6	7.5
Pump for disch lock to hot well	5.6	7.5
Pump for pressure cool	18.7	25.0
Drive Screws(total)	9.0	12.0
Pump for atmospheric cool (per car)	2.8	3.8
Hydraulic System	30-37	40-50

Cars between Locks	*Approx. KW*	*Approx. HP*
5	96	128
10	123	165
15	154	207
20	179	240
25	207	277

Personnel: Only *one* operator is needed to run the UFS.

Estimated Costs: The UFS as configured in the drawings with 27 cars between locks, one loader and unloader will cost approximately $ 2,674,000. This includes 54 cars total.

The Boiler Room is located adjacent to the UFS so that the heated water supply required for the UFS is conveniently located so as to minimize piping distances.

C. Activity Relationship Diagram

As indicated in Figure 21, the UFS is 131 feet long with 27 trolley cars, each holding 144 Tray Packs. The infeed conveyors are designed to handle Tray Packs at 40 cpm. Trolleys circulate through the UFS in clockwise rotation being incrementally moved through the UFS by a worm gear drive.

Cooling of the trays occurs at the end of the cooking cycle, then the trolleys are moved to the unloading conveyor where they are fed to the packaging and palletizing area.

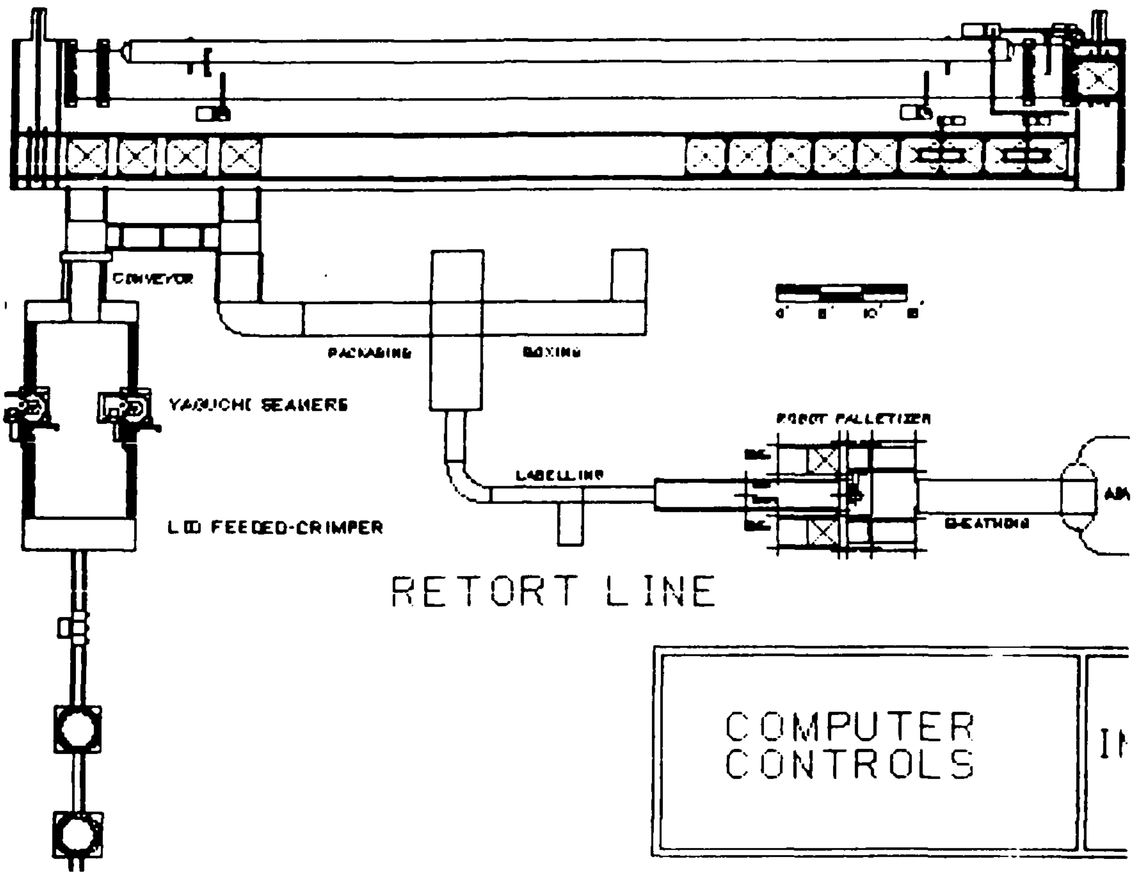

Figure 21 Sterilization area layout

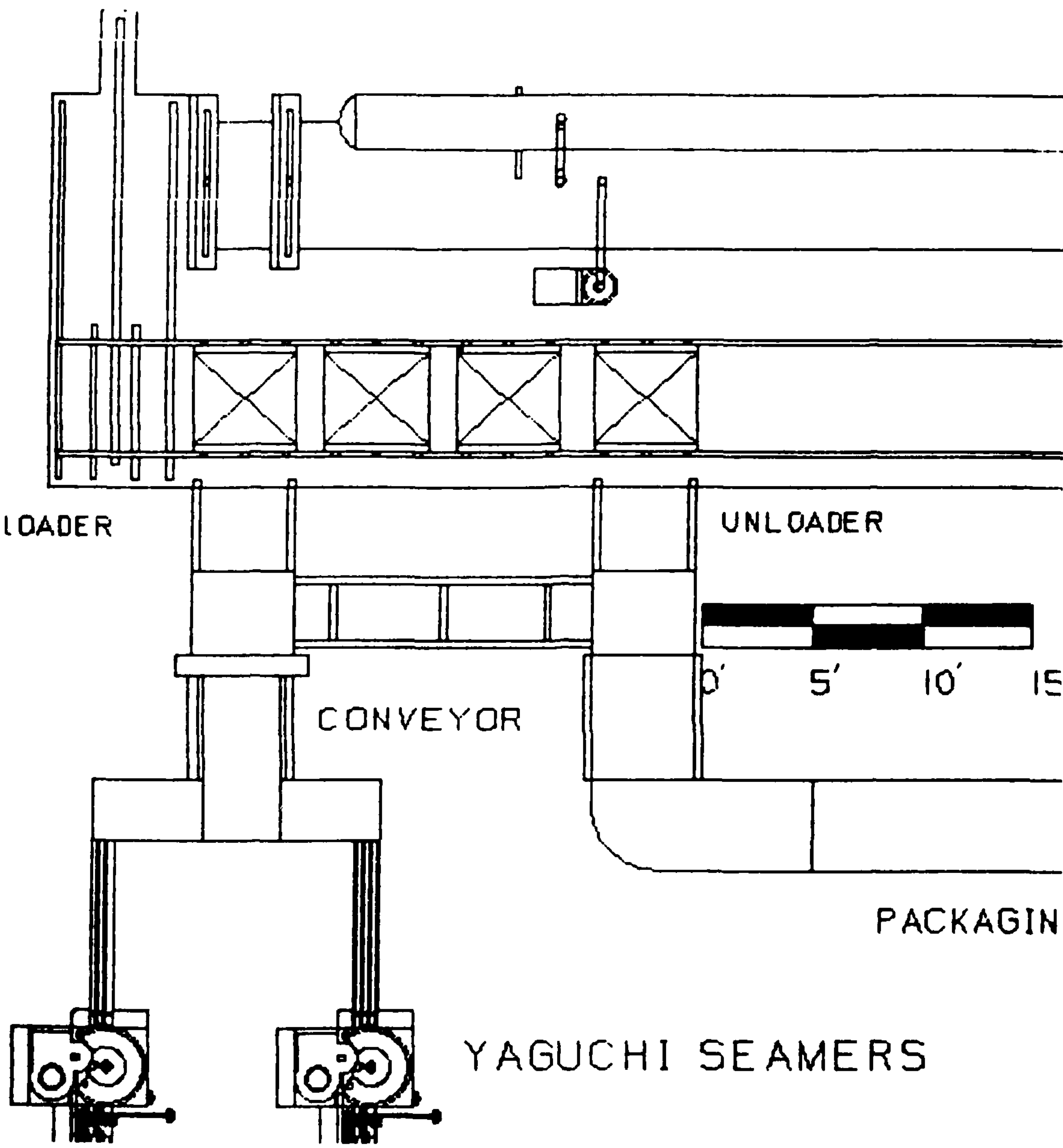

Figure 22 UFS loading/unloading area

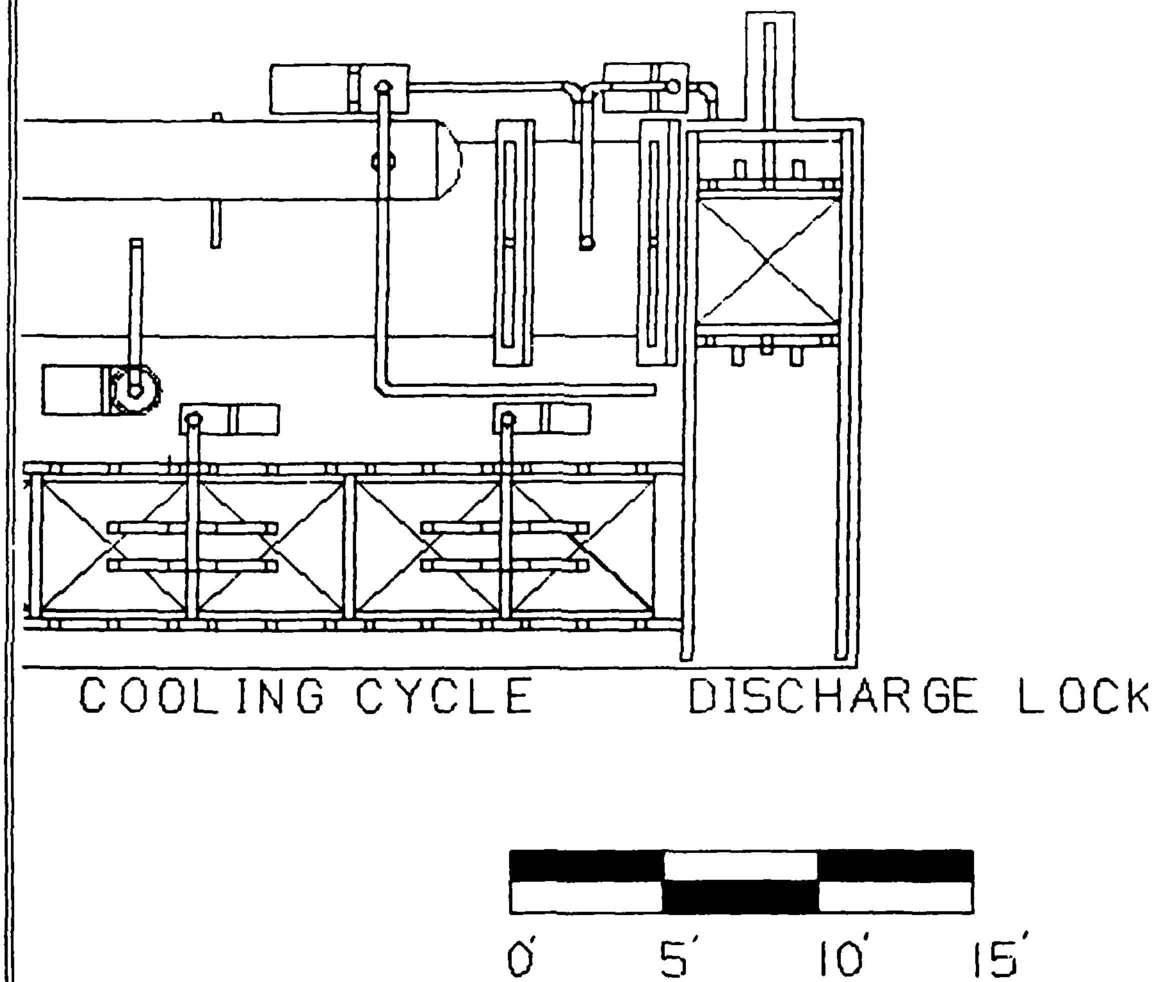

Figure 23 UFS trolley discharge and cooling area

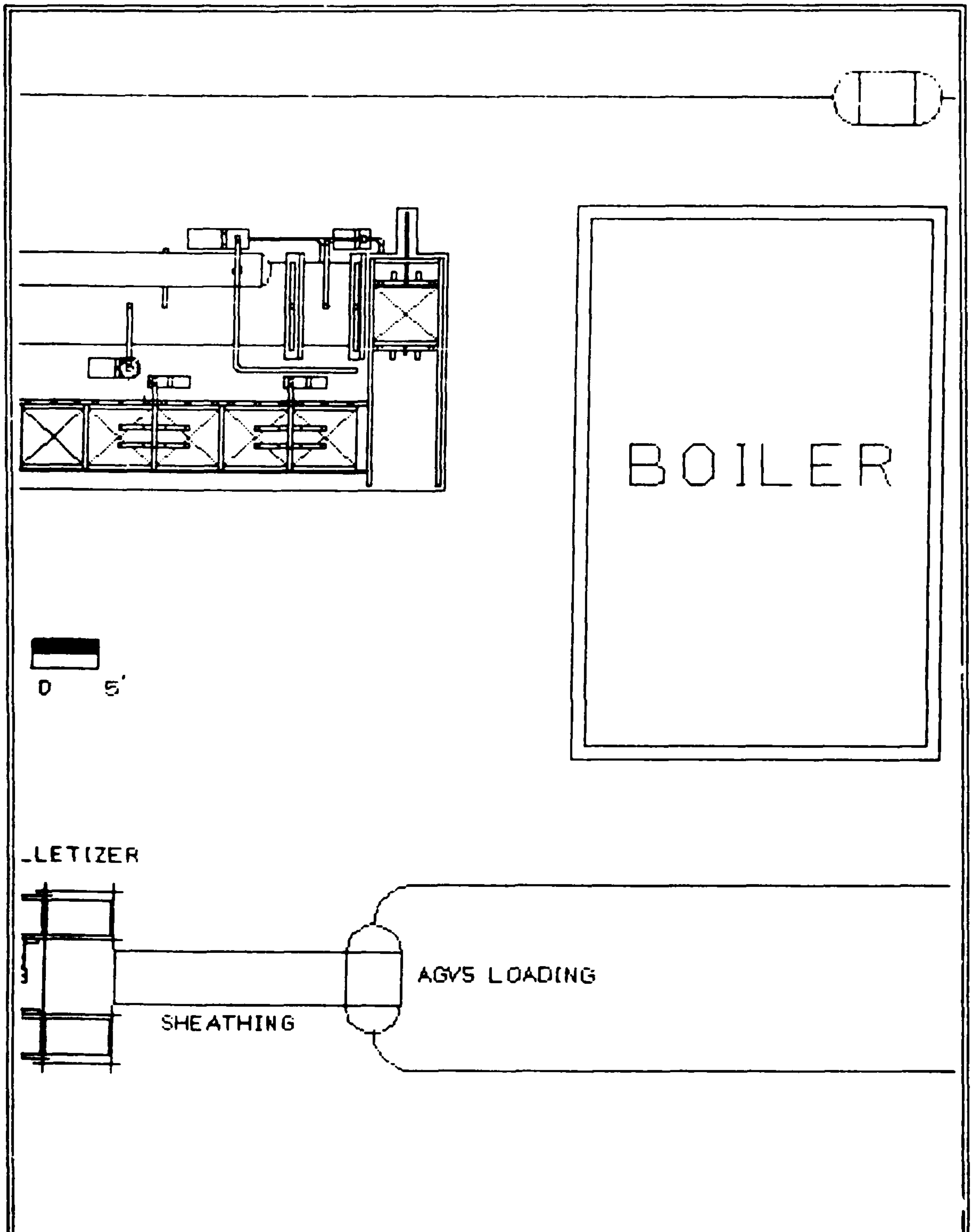

Figure 24 Boiler room

C H A P T E R 7. Packaging Area

A. Activity Description

This *Packaging Area* of the plant will house a number of pieces of automated machinery designed to label, box, palletise and sheathe the Tray Packs ready for shipment. In addition, the Computer Controls and Incubation Room are located here since they are centrally located to the entire plant operation as can be seen in the layout diagram.

The *Packaging Area* should include:

- o Automated Case Former
- o Automated Pad Inserter
- o Automated Can Labelling/Marking
- o Automated Conveyor Transfer Equipment
- o Robot Palletizer/Depallitizer
- o Pallet Sheathing Equipment
- o Computer Controls Room
- o USDA Laboratories & Incubation Room

B. Activity Relationships

This *Packaging Area* of the plant is directly adjacent to the *Sterilization Area* and the Shipping Warehouse. Automated conveyors link the Sterilizer with the *Packaging* and *Palletizing* areas so as to minimise material handling distances.

The *Packaging Area* is designed so that the retortable items have their own packaging operations as well the the Oven Bake items. This duplication is felt to be necessary in order to streamline operations as well as accommodate the different throughput rates of the products.

The AGVS system is integrally linked to this *Packaging Area* so that once the pallets are sheathed they can be moved to the Shipping Warehouse.

The *USDA Laboratories & Incubation Room* is adjacent to this area so that the USDA scientists may have their own work areas(offices with bath & lockers) nearby the production area. Also, the Incubation room is adjacent to this lab area so that samples drawn from the production lots can be safely stored in a separate controlled environment.

Finally, the *Computer Controls* room for the operation of the entire plant is located in this area. Separate control systems for the AS/RS, AGVS, UFS and other automated systems throughout the plant would be networked together in this room. The *Computer Controls* room is convenient to the entire plant operation, for *visual and physical* control, yet separate to maintain *climate control and security.*

Figure 25 illustrates the *Packaging Area*, and Figures 26 through 28 the component parts.

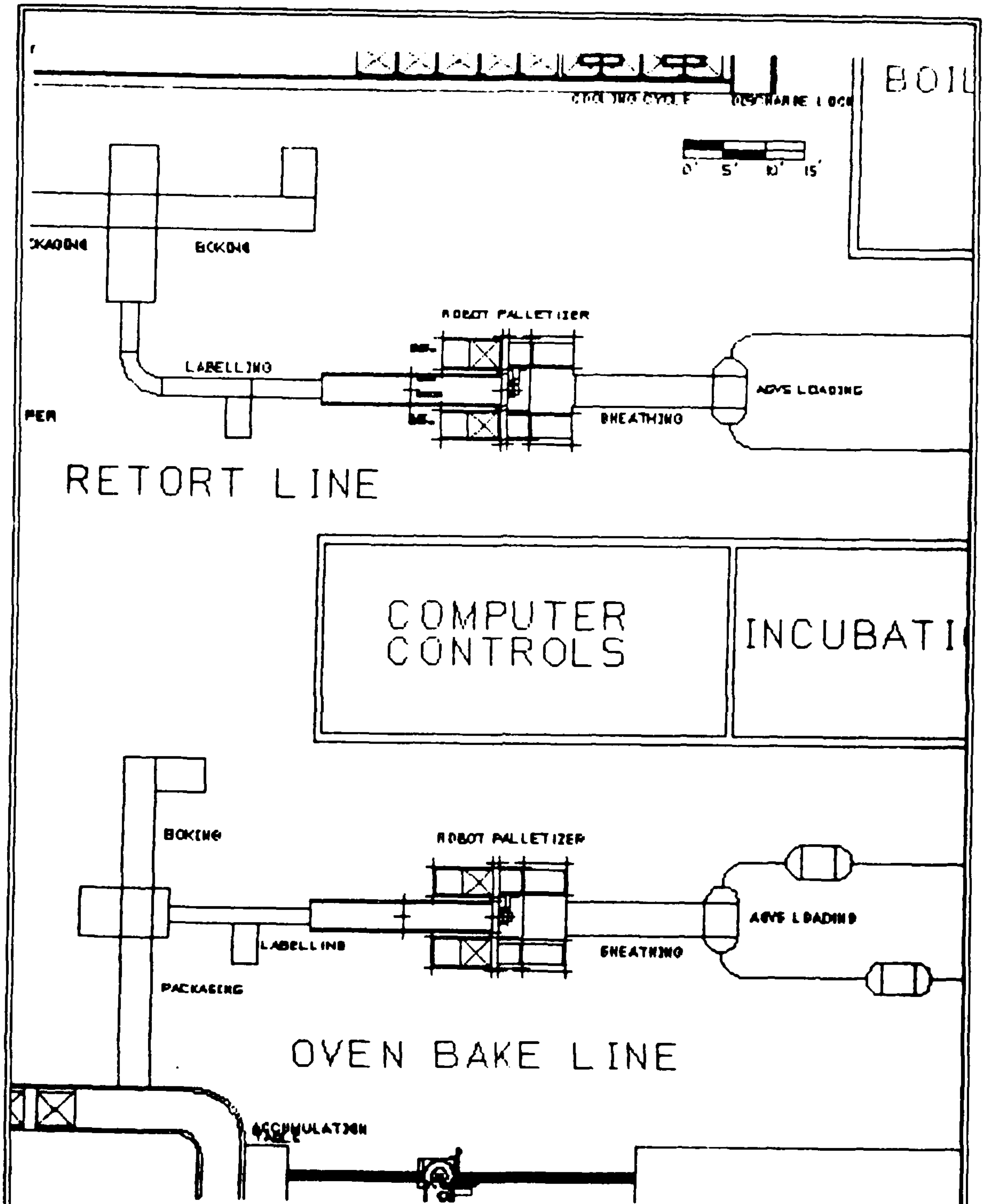

Figure 25 Packaging area layout

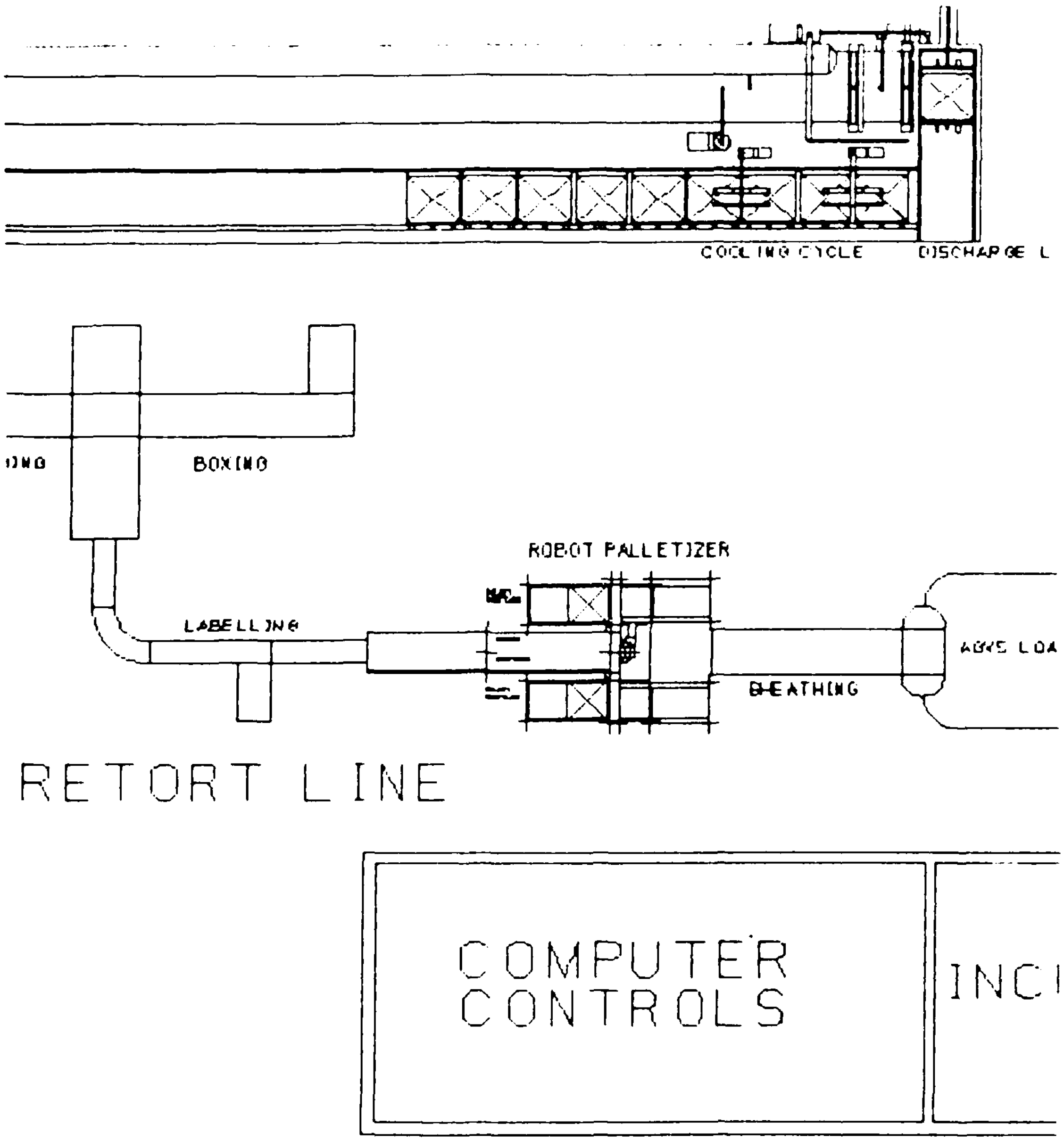

Figure 26 Retort packaging line

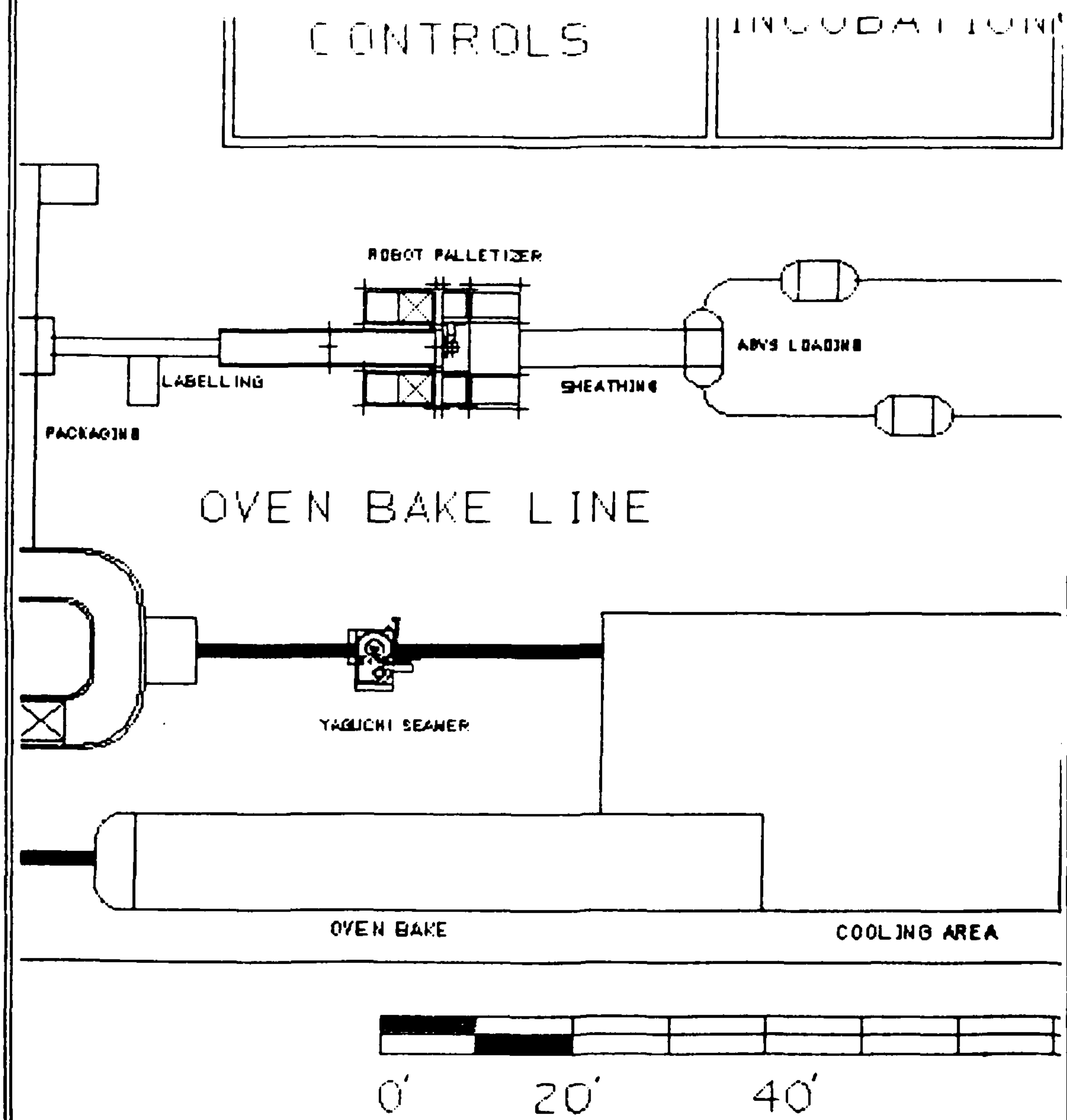

Figure 27 Oven bake packaging line

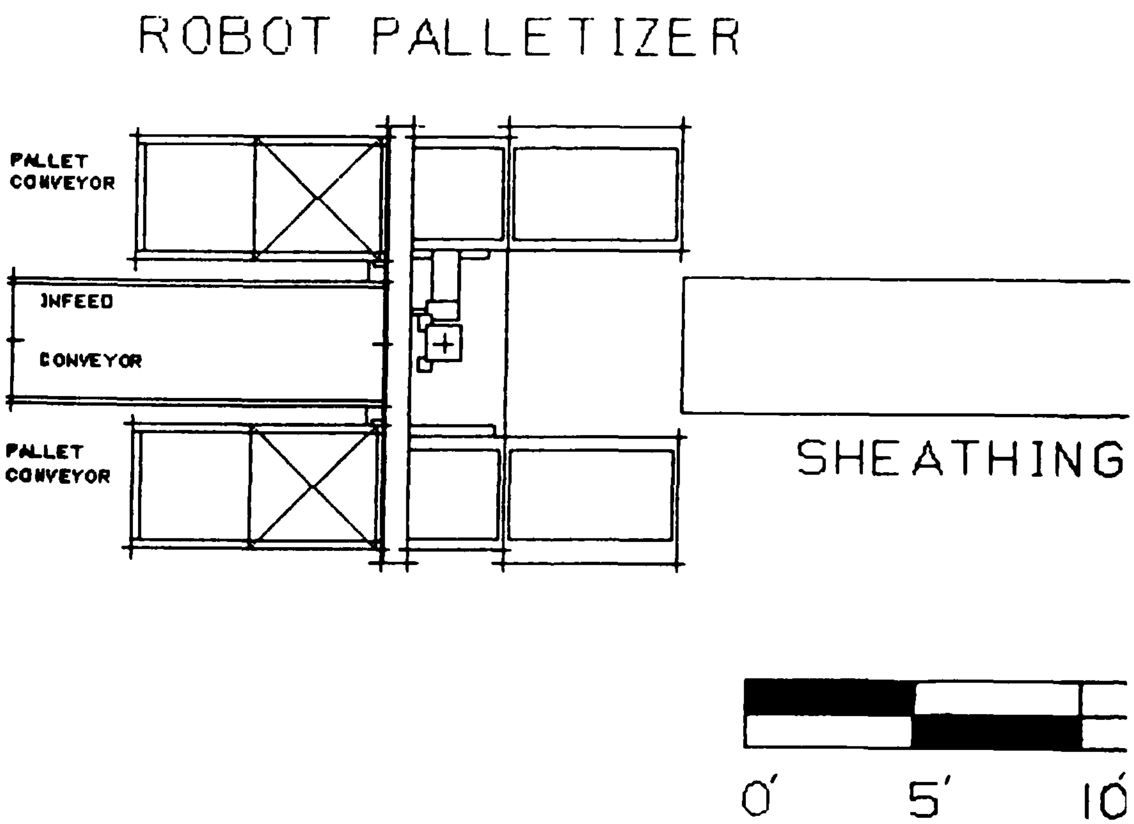

Figure 28 Robotic palletizer w/ AGVS interface

C H A P T E R 8. Shipping Warehouse

A. Activity Description

The *Shipping Warehouse* constitutes the end-point of the Tray Pack assembly process. As in the *Receiving Warehouse*, an AS/RS and AGVS system are used to manipulate the pallets accommodating the Tray Packs.

The detailed parts of the *Shipping Warehouse* include:

- o Storage for Tray Packs ready for shipping
- o Damaged Can Storage
- o Shipping Dock/ Truck Turnaround/ Rail Linkage
- o Garbage Collection

B. Activity Relationships

The *Shipping Warehouse* is essentially a mirror-image of the *Receiving Warehouse* but only accommodating the completed Tray Pack assemblies. Because of the unusual requirement to store production batches for 20 days, this Warehouse should be sised to accommodate production for 20 days.

Based on a tabular breakdown in the first part of this report, 20 days production would require a minimum of $1,365,006$ Tray Packs for the 44 menu items. This figure does not include damaged or returned cans, holdover shipments or excess production. In order to finalise the *Shipping Warehouse* design figure to include these contingencies, let's perform the following analysis.

If we consider that the *Shipping Warehouse* has a capacity of K units and it must store n different commodities for which the stock items are known, then the required maximum capacity of the i^{th} commodity k is given as:

$$\sum_{i=1}^{n} k_i = K \quad or \quad K = \sum_{i=1}^{n} k_i + r\sum_{i=1}^{n} \sigma_i$$

where r = a risk factor associated with the stock distribution

Let's establish the validity of the above formula.

The proportion of capacity taken up by the maximum required for the i^{th} item is given as:

$$\alpha_i = \frac{k_i}{k}$$

Further, the average stock of the i^{th} item is given by k_i with the total average stock κ, given by:

$$\sum_{i=1}^{n} k_i = \kappa$$

For our problem, if the production of Tray Packs is symmetrical, then the distribution of total stock will approach the normal distribution with average equal to the sum of the averages and variances equal to the sum of the variances, i.e.

$$K = \sum_{i=1}^{n} k_i + r\sum_{i=1}^{n} \sigma_i$$

Finally, with an estimate of the standard deviation of production on each of the Tray Pack items, we can estimate the expected maximum production. As a method of estimating the standard deviation, we shall employ the coefficient of variation which is given by:

$$\nu = \frac{\sigma}{\mu}$$

If we assume ν to be approximately 0.25, which assumes a low variance, then σ will be approximately 341,252 Tray Packs, given an average total output of 1,365,006 trays per 20 day cycle. If further, we assume a risk factor of 3 (Three sigma-limits) then, the maximum expected demand will be 2,388,760 trays per 20 day cycle. This is a reasonable estimate of the maximum production and will be used to size the overall warehouse.

In comparison to conventional technology to warehouse Tray Packs on pallets, in order to accommodate 2,400,000 Tray Packs stacked 48 cartons to a pallet, approximately 12,500 pallet loads would be required for a grand total of around 109,125 square feet (330.34 feet on a square side). Aisles betwen pallet racks are 10 feet wide and the total height of the stacked pallets is limited by the vertical lifting capabilities of the conventional fork-lift truck. The Shipping Warehouse indicated in the diagram of Figure 29 accommodates the same number of pallets as a conventional warehouse in only 59,774 square feet. This is a gross savings of 49,351 square feet, a savings of 45.2%.

Finally, if an a AS/RS warehouse were chosen with a higher ceiling, additional savings in square footage construction costs would occur. While the main emphasis of this report has not been on space saving economies for storage and material handling of Tray Packs, such type of automation as is possible with AS/RS and AGVS systems should prove to be quite effective.An illustration of the AGVS system with the *Packaging Area* is Figure 30.

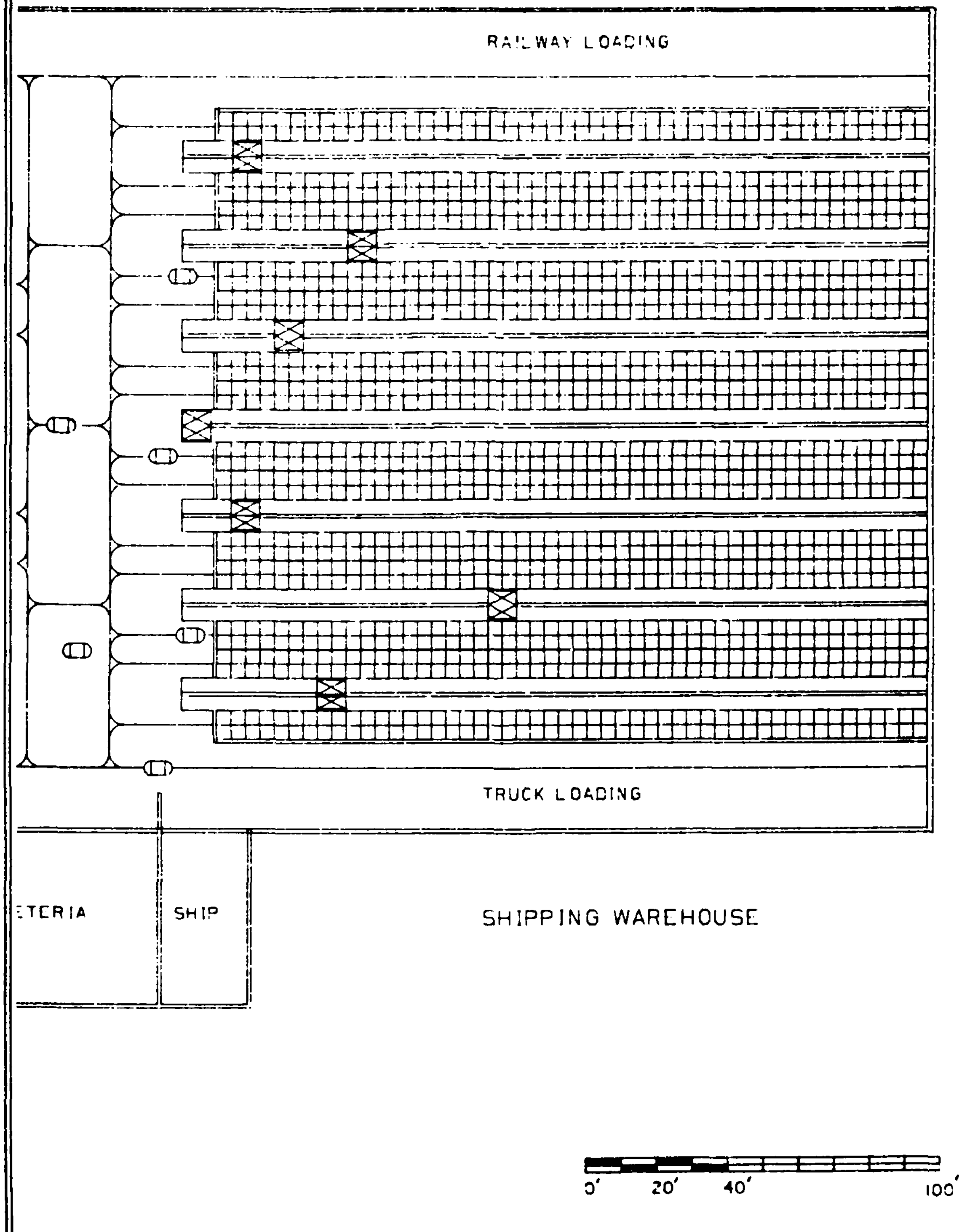

Figure 29 Shipping warehouse

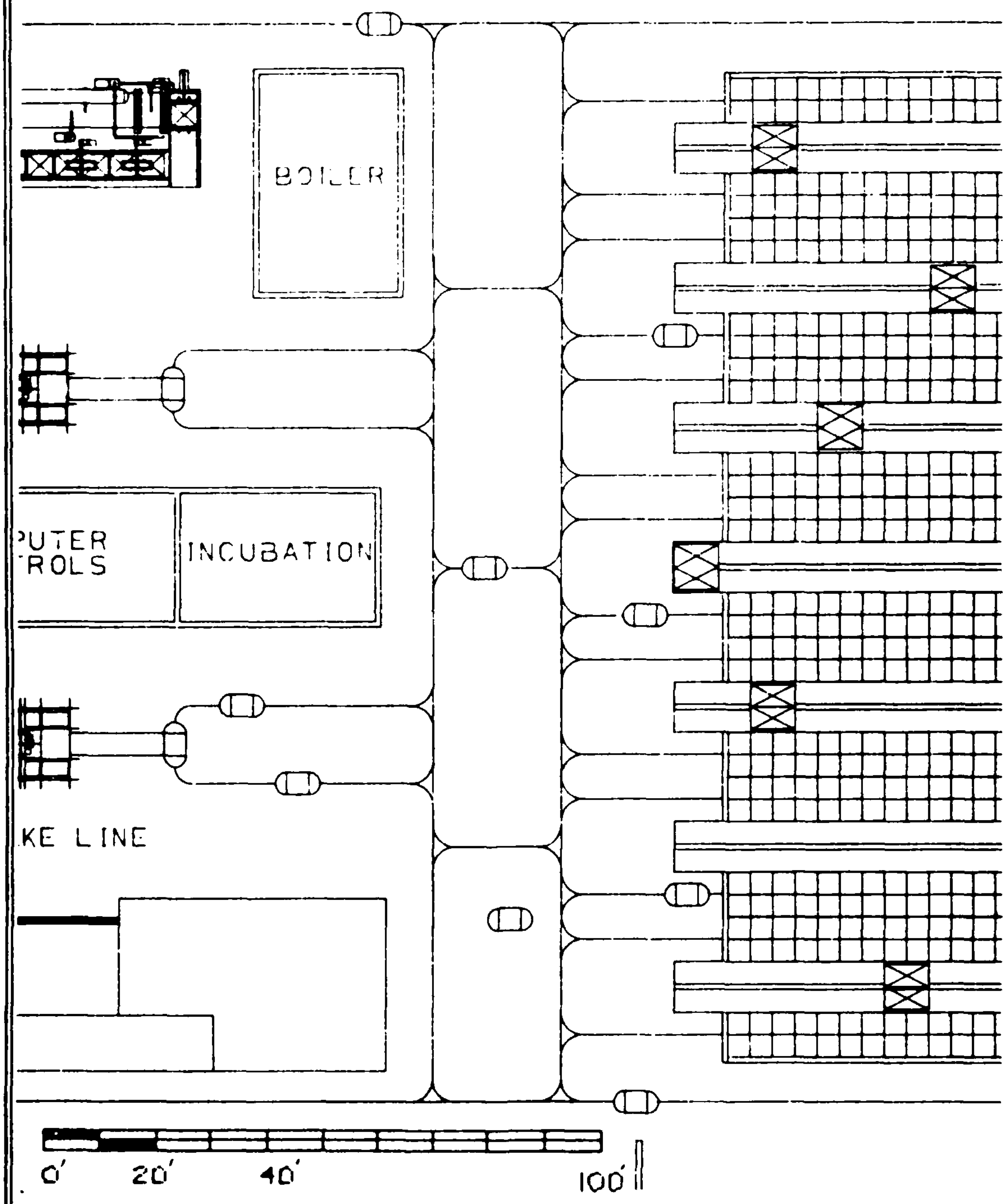

Figure 30 AGVS interface with packaging area

CHAPTER 9. Administration/Staffing

A. Activity Description

The number of activities included within this activity category are quite extensive given the range of duties the staff must carry out.

- Managerial Offices
- Secretarial
- Plant Engineer
- Quality Assurance
- General Engineering
- Maintenance & Janitorial Shops
- Test Kitchen
- Visitor Reception
- Cafeteria
- Parking (Visitors/Staff)

B. Activity Relationships

The *Administrative/Staffing* area is located in the plant where it may be least affected by the expansion of the plant operations, however, it is centrally located to the plant operations for maximum security and control reasons. The USDA Laboratories have already been included along with the Incubation room requirements covered in Chapter 7.

The Administrative area is 429 feet long by 49 feet wide, or roughly 21,021 square feet. This is a generous allotment but considering the range of functions including expansion over the years, this allocation is not unreasonable. Since the focus of the project has been on the manufacturing layout, no detailed layout for the *Administrative/Staffing* area has been provided other than its general location and configuration which is indicated on Figure 2.

CHAPTER 10. Summary and Conclusions

In order to conclude this report, a final summary cost and personnel estimate of the plant together with specific recommendations and issues for future study will be presented.

A. Cost and Personnel Estimate

The Cost & Personnel Estimate is broken down into the main activity areas within the plant. The building is to be a pre-engineered structure so the cost/square foot of the construction is based on this concept. In general, a cost per square foot of $45.00 is used to estimate the cost of the building. Besides this, each indivdual equipment item of major significance is also itemised, in particular, the equipment items of the *Assembly/Filling Area*. Along with the cost itemisation, the number of personnel necessary to operate and maintain the equipment is estimated.

Table 4. Activity and Cost Estimate

Items	Quantity	Personnel	Cost/Quantity	Total $
I. Receiving Warehouse				
o AS/RS Building	52,440 s.f.	2	$500,000 per aisle	3,500,000
-(Racks, Refrigeration & AGVS Trucks)				
			I. Sub-Total	3,500,000
II. Preparation Area				
o Multi-Step Building Area	13,908 s.f.	10	$45.00/s.f.	625,860
o Oven-Bake Preparation Area	9,638 s.f.	10	$45.00/s.f.	433,710
o Wall-Mounted Equipment			$100,000	100,000
-(Ovens, Kettles, Sinks)				
			II. Sub-Total	1,159,570
III. Filling Area				
o Building Area	37,017 s.f.		$45.00/s.f.	1,665,765
-(includes Sterilization Area)				
o Gravity Filler	1		$50,000	50,000
o FMC #676 Piston Filler	2		$120,000	240,000
o FMC #676 Liquid Filler	2		$90,000	180,000
o Yamato CMO 3-L Check-Weigh	2		$21,500	43,000
-(with Air-pusher reject)				
o Yaguchi Vertical Lid Feeder	1		$18,000	18,000
o Yaguchi Oven-Bake Crimper	1		$30,000	30,000
o Yaguchi YR-SV Seamers	3		$150,000	450,000
o Ovens for Oven Bake items	1		$150,000	150,000
o Cooling Line for Oven Bake items	1		$150,000	150,000
o Oven-Bake Trolley Racks	1		$50,000	50,000
o Can Washers	4		$30,000	120,000
o Powered Conveyors	16" x 100ft.		$32.00 per foot	3,200
-(Powered Belt conveyor on roller)				
			III. Sub-Total	3,149,965

IV. Sterilization Area				
o FMC-UFS Sterilizer	1	1	$2,674,000	2,674,000
o Boiler Room	1,107 s.f.	1		
-(s.f. costs already included)				
			IV. Sub-Total	2,674,000
V. Packaging Area				
o ABC-APS Automated Case Former	2	1	$33,000	66,000
o Automated Pad Inserter	2		$32,000	64,000
o Can Labeller	2		$10,290	20,580
o Roller Conveyors	2@ 48"x 92 ft		$190.00/ft	34,960
-(Powered roller Conveyor)				
o FMC Model 500 Robotic Palletizers	2		$60,000	120,000
o ABC Pallet Sheathers	2		$35,000	70,000
o Computer Controls Room	1	2		
-(s.f. & eqpt. costs already included)				
o Incubation Room	875 s.f.	1		
-(s.f. costs already included)				
			V. Sub-Total	375,540
VI. Shipping Warehouse				
o ASRS Building	52,440 s.f.	2	$500,000 per aisle	3,500,000
- (Racks, AGVS Equipment, etc.)				
			VI. Sub-Total	3,500,000
VII. Administrative/Staffing				
o Building Area	21,021 s.f.		$45.00/s.f.	945,945
o Managerial		4		
o Secretarial		8		
o Engineering & Qual. Cntrl.		4		
o Maintenance & Janitorial		8		
o Test Kitchen		4		
o Cafeteria		4		
o Security		4		
			VIII. Sub-Total	945,945
VIII. Building Services				
Plumbing, Mechanical, and Electrical	105,201 s.f.	6	$15.00 s.f.	1,578,015
			VIII. Sub-Total	1,578,015
IX. Grand Totals				
Personnel Totals		72		
Cost Totals				16,883,035

The cost for all the plant and equipment comes out to around $80.36 per square foot for the entire Tray Pack facility.

B. Specific Recommendations

A partial list of recommendations appropriate for continued examination beyond the current project report is presented below. The recommendations are broken down into three major categories, namely: Engineering & Planning, Engineering Design, and Engineering Control.

B.1. Engineering & Planning

1. Systemwide Cost Analysis

A system-wide cost analysis of the production, manufacturing and distribution of Trays Packs as currently carried out by manufacturers would begin to pinpoint problem areas and suggest where cost savings could be enacted to reduce and control the overall costs of manufacturing Tray Packs.

Supporting Information:

As is apparent from this study and the past ones, there are many economic and financial aspects of the production, manufacturing and distribution of Tray Packs that could be improved upon. Cost and Quality control pervades all facets of the Tray Pack process: from the distribution and warehousing of raw materials, preparation and assembly of menu items, closing and sterilisation of the cans, and onto the eventual packaging and shipping of the completed assemblies. A detailed survey and data base construction of current cost information for the entire Tray Pack manufacturing process would clearly aid in the prioritisation of efforts to reduce and control costs within the program.

2. Optimisation Software

A number of problems with Tray Pack manufacturing and production process lend themselves to software optimisation development at the system planning level, among which the following problem area appears most relevant: Tray Pack Facility Optimisation

Supporting Information:

As a follow-up analysis building upon the results of the software demand analysis program entitled NATPRO,[5] an optimisation analysis could be performed to examine the number of facilities and production lines necessary to meet Tray Pack demand with minimum cost. The optimisation program would have to consider the producer's production rates for the individual items and any facility capacity constraints impinging on the required demand for the product. Linear and Integer Programming models could be constructed to carry out this optimisation analysis.

B.2 Engineering Design

The set of recommendations contained in this section concerns the detailed equipment designs for the Tray Pack lines. While the present report focused on the location and configuration of the lines within the facility, time has not permitted the detailed investigation of the mechanical design of each piece of equipment as noted in the report.

1. Spillage Problem:

Identify and develop methods and/or devices to control the spillage problems in transferring trays into the seamer thus enabling all products to be produced at a constant, maximum rate.

Supporting Information:

Current production rates are limited mainly by the speed of the seaming operation. There are two factors that influence seaming rates:

- The inherent maximum speed of the machine (which presently ranges from approximately four to thirty cans per minute)

- Spillage problems met in transferring cans with low viscosity products from the last filler into the seamer.

Producers are currently limited by spillage problems to about eight cans per minute on some items. If lids could be placed on the cans and held in place until the can is in the seamer, production speeds for all products should increase to at least 20 cans per minute. One possible method of holding the lids in place would be to develop and use a clip attachment and removal system (the removal system becoming part of the seamer itself).

2. Filling Problem:

Adopt or develop mechanical aids to speed tray filling operation.

Supporting Information:

At the present time, placement of specific count items into the trays is done by hand. The large number of menu items precludes development of devices to totally replace hand placement. Moreover, an important inspection operation is eliminated if such totally mechanical placement is achieved. Nevertheless, collection and arrangement of pieces into a tray loading pattern is practiced in a variety of food processing lines. Selection and implementation of equipment to facilitate such preassembling should allow labor and physical space requirements for tray filling to be reduced. The Gravity and Shaker Filler concepts which have been indicated within this report represent the type of items needed.

Problems involved in placement of small particulates and pumpable liquid and semi-liquid foods are not as difficult to overcome as those with specific count items. Nevertheless, problems with uniformity, head space control, and cleanliness of the can seal area that were raised by various producers,point to the need for further development work in this area as well.

3. Experimental Line Development:

Develop and assemble a full speed developmental and demonstration production line based on the design concepts of the present report.

Supporting Information:

In the past, there has been little sharing of information between competitive producers of Tray Pack foods. Moreover, as contracts to date have been for small quantities, there has been little incentive to investigate semi-mechanised filling devices, lid clip arrangements, and work station improvements. Proper investigation of these topics would benefit all producers and would prevent duplication of research efforts if performed in a neutral environment.

B.3 Engineering Control

The recommmendations in this section concern control of producibility, namely the inventory, scheduling, line reliability, congestion and maintainability of the production lines related to producibility. Since most producers did not have well-engineered production lines, control problems of Tray Packs have not really emerged as key issues at the current time. Given our understanding of the type of control problems normally associated with production lines, these problems will eventually surface, so preliminary planning and software development in this area will eventually have some long range impacts. There are two sets of recommendations in this area, a) Multi-Product Batch Scheduling and b)Digital Simulation of the the Product Lines.

1. Multi Product Batch Scheduling

Develop software for scheduling of multi-product items within food processing plants so that due dates and resources within the plant are optimised.

Supporting Information:

As Tray Pack volume increases, utilization of resources (e.g., equipment, labor, space) will intensify between Tray Pack items and commercial items produced at a site. Multi-product resource scheduling would be concerned with developing and utilizing software tools so that Tray Pack items and commercial items could be scheduled simultaneously and due dates and resource utilization could be optimized. Also, these software tools would be developed for personal computers so that producers would have ready, easy access to them.

2. Digital Simulation of Product Lines

Develop simulation and analytical models for the production lines via a digital simulation language and other network flow models so that changes in technology, line configuration, workstation changes can be examined as to their impact on production rates. This type of simulation analysis is not only useful for checking actual production rates before the lines are built, but for controlling problems associated with machine breakdowns, congestion, and overall line reliability.

Supporting Information:

Flow analyses could be developed for classes of tray items, and ultimately, each tray item if necessary. If a simulation of each item were developed, this information could be shared between producers as they are developing similar product lines so that producers do not make the same mistakes previously made by other producers, especially as new equipment items, labor charges are made, etc. The programs could be part of a technology transfer so that individual producers could have the software available on Personal Computer (PC) micros to set-up and test the line configurations before actually constructing them.

C. References

1. *Producibility Engineering and Planning for Tray Pack Foods* by J. MacGregor Smith, J.T. Clayton, J. R. Rosenau and C.J. Lizak; to be published as a US Army Natick Technical Report.
2. Research and Development Associates for Military Food and Packaging Systems, Inc. *Minutes of Committees and Subcommittees of the R & D Associates, Half Steam Table, Table Tray Committee, 10* (Fall 1985).
3. Pegden, C. Dennis, *Introduction to SIMAN*. Systems Modeling Corporation, Calder Square P.O. Box 10074 State College, Pennsylvania, 16805-0074, 1984.
4. Information provided by the FMC Corporation, Mr. Paul J. Aguilar, Applications Engineer, Correspondance on November 19, 1985.
5. *Producibility Engineering and Planning for Tray Pack Foods* by J. MacGregor Smith, J.T. Clayton, J. R. Rosenau and C.J. Lizak; to be published as a US Army Natick Technical Report.

Appendix A. Manufacturers Listing

The following Appendix itemizes manufacturers of specialized equipment critical to the operation of the plant. The manufacturer's are associated with the following four areas of the plant: The Receiving and Shipping Warehouses, the Preparation and Filling Area, The Sterilization Area, and finally, the Packaging Area.

Receiving and Shipping Warehouses

AS/RS and AGVS SYSTEMS

Eaton-Kenway
attn: Mr. William B. York
515 East 100 South
P.O. Box 4250
Salt Lake City, Utah 84102

Hartman Material Handling Systems, Inc.
attn: Mr. Edward J. Budill
66 School Street
Victor, New York 14564

Jervis B. Webb Company
attn: Mr. Carl M. Kaltwasser
Executive Plaza
540 Pennsylvania Avenue, Suite 321
Fort Washington, Pennsylvania 19034

SPS Technologies
attn: Mr. Charles D. Wenzel
Township Line Road
Hatfield, Pennsylvania 19440

Litton UHS
3101 Old Hayneville Road
P.O. Drawer 177
Montgomery Alabama 36195

PREPARATION AND FILLING AREAS

General Preparation & Filling Equipment

FMC Corporation
attn: Mr. Dave Isaccs
103 East Maple Street
Hoopeston Illinois 60942

Groen Division/Dover Corporation
1900 Pratt Boulevard
Elk Grove Village, Illinois 60007

Fillers

Solbern Corporation
attn: Mr. Bill Kalmar
8 Kulick Road
Fairfield, New Jersey 07006

Packaging Research Corporation
attn: Mr. Rodney D. Wicklund
2852 S. Tejon
Englewood, Colorado 80110

Check Weighers/ Rejects

Barkley & Dexter Laboratories, Inc.
attn: Mr. Sam Gudgel
50 Frankfort Street
P.O. Box 307
Fitchburg, Massachusetts 01420

Lid Feeder, Crimper & Seamers

Industrial Marketing International
attn: Mr. Heinz Grossjohan
P.O. Box 503 – 1-3 Broad Street
Kinderhook, New York 12106

FMC Corporation
attn: Mr. Richard Houtzer
Food Processing Machinery Division
2300 Industrial Avenue Box A
Madera, California 93639

Can Washers

Alvey Washing Equipment
attn: Harley Huddle
11337 Willimason Road
P.O. Box 41031
Cincinnati, Ohio 45241-0031
(513) 489-3060

STERILIZATION AREA

Retorting Equipment

FMC Corporation
attn: Mr. Richard Houtzer
Food Processing Machinery Division
2300 Industrial Avenue Box A
Madera, California 93639

Industrial Marketing International
attn: Mr. Heinz Grossjohan
P.O. Box 503 – 1-3 Broad Street
Kinderhook, New York 12106

Packaging Area

Case Packers, Pad Inserters, and Sheathing Equipment

ABC Packaging Corporation
attn: Mr. James Hooker
811 Live Oak Street
Tarpong Springs, Florida 33589

Western Packaging Systems, Ltd
attn: Mr. John J. Fisher
P.O. Box 2287
Naperville, Illinois 60565

Palletizers and Conveyors

FMC Corporation
attn: Mr. Jim Klaber
103 East Maple Street
Hoopeston Illinois 60942

Litton UHS
3101 Old Hayneville Road
P.O. Drawer 177
Montgomery Alabama 36195

Labellers

Dalemark Industries Inc.
attn:Maria Rau
950 Airport Road
Lakewood, New Jersey 08701

Ankler Labelers Corp.
Briggs Road
Mt. Laurel, New Jersey 08054

American Technologies
1301 Dugdale Road
Waukegan, Illinois 60085

Appendix B. Selected Product Literature

The following drawings and figures (B.1 through B.4) were taken from product literature supplied by the following manufacturers:

Eaton-Kenway Corporation, maker of AS/RS and AGVS equipment.

FMC Corporation maker of robotic palletizers.

These products were selected because of their unusual design features and relevance to the details of the plant design. Other manufacturers listed in the previous Appendix also make similiar or related types of equipment.

Figure B.1 AS/RS Aisles w/ AGVS interface

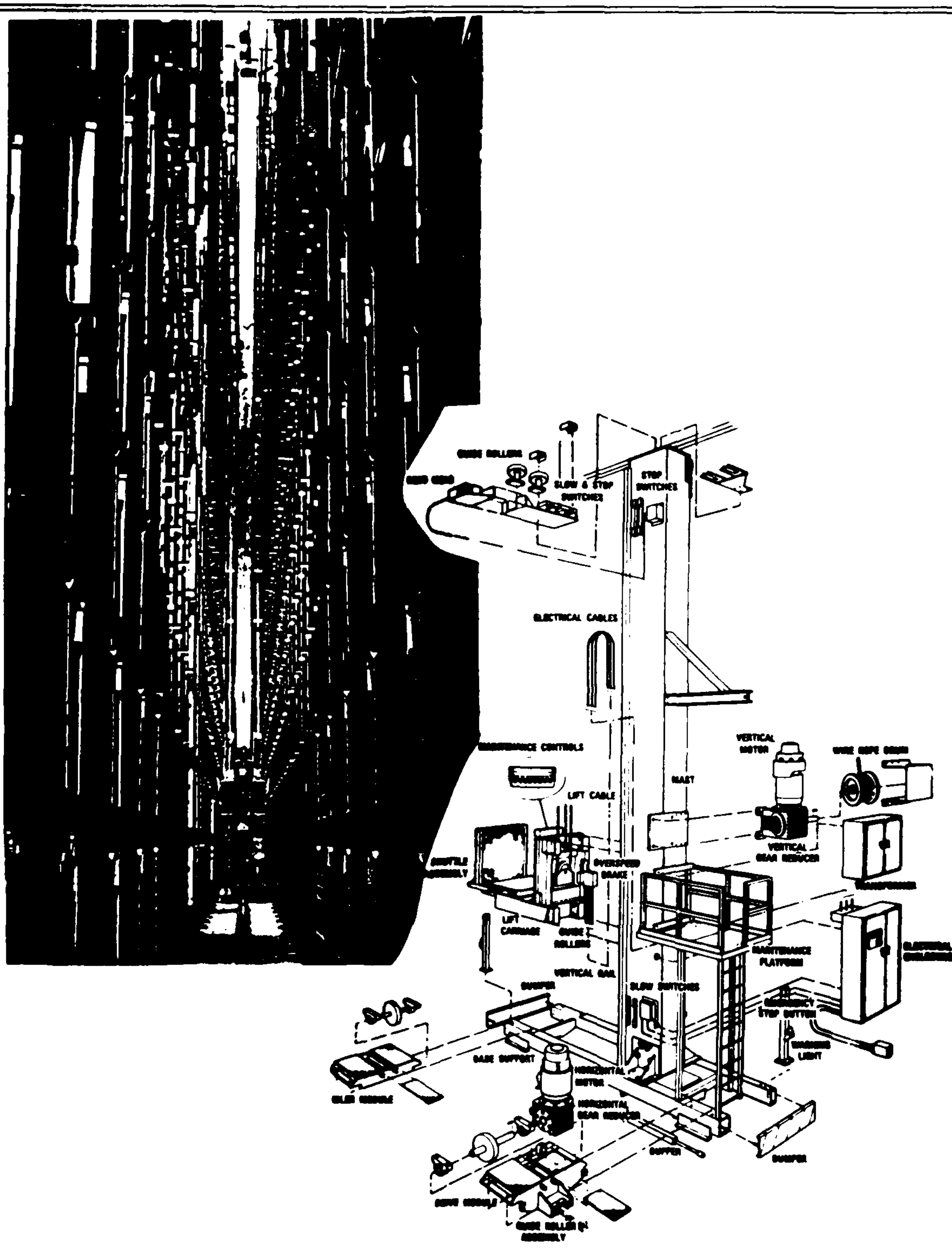

Figure B.2 AS/RS Aisles

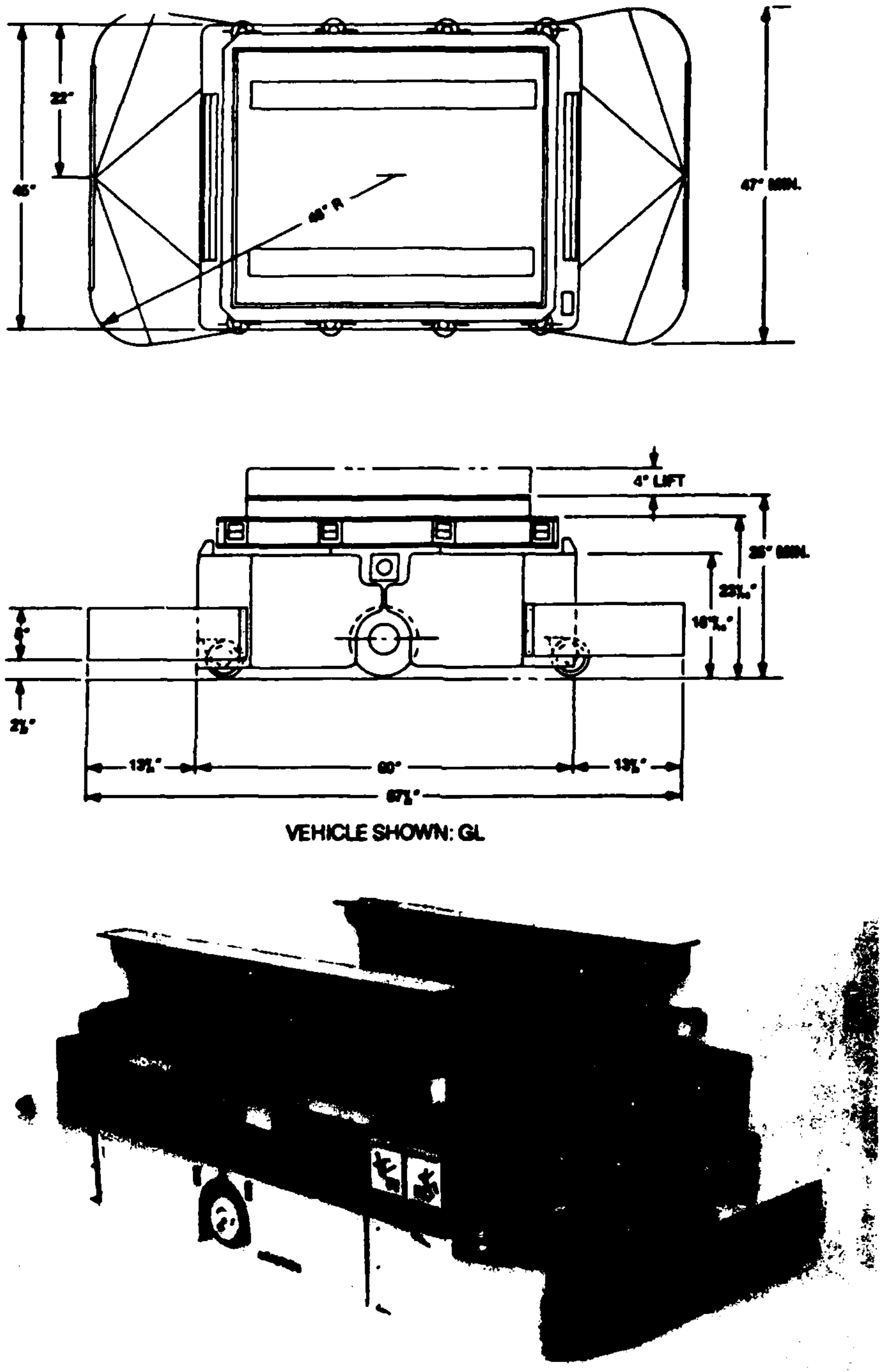

Figure B.3 AGVS Products

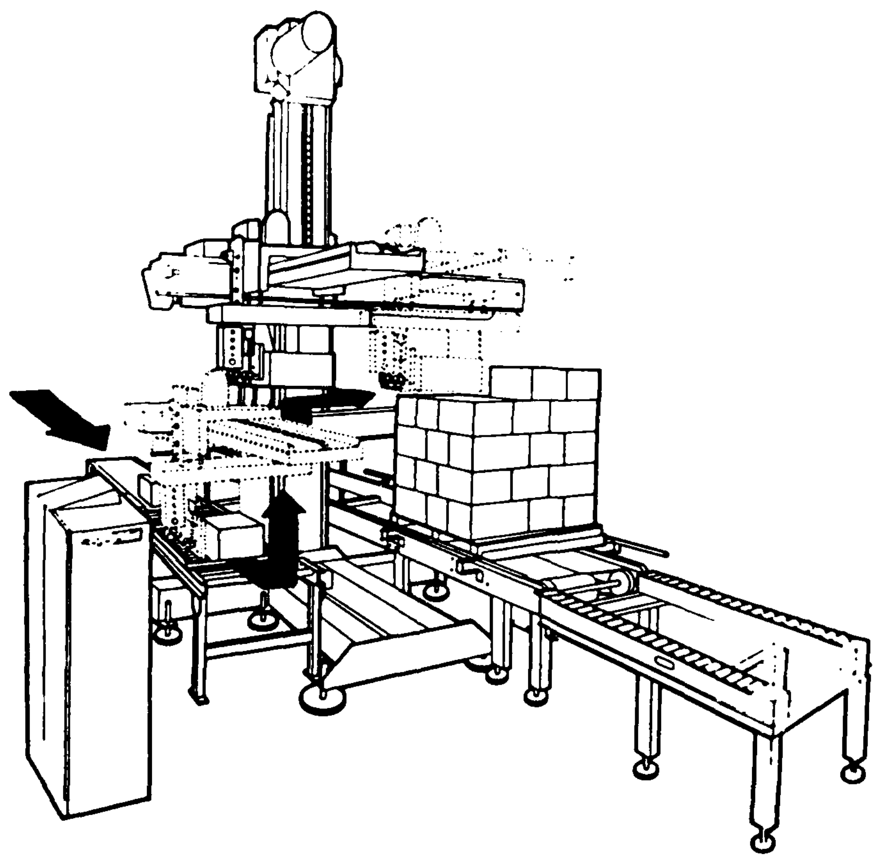

Figure B.4 Robotic Palletizers

Appendix C. SIMAN Computer Model

```
SIMAN MODEL PROCESSOR RELEASE 3.0
COPYRIGHT 1985 BY SYSTEMS MODELING CORP.

BEGIN;
10      CREATE:ED(1):MARK(1);
20      COUNT:1;
;
30      QUEUE,1;
40      SEIZE:CONV1;
50      DELAY:ED(2);
60      QUEUE,2;
70      SEIZE:WASHER1;
80      RELEASE:CONV1;
90      DELAY:ED(3);
100       QUEUE,3;
110       SEIZE:CONV2;
120       RELEASE:WASHER1;
130       DELAY:ED(4);
140       QUEUE,4;
150       SEIZE:CONV3;
160       RELEASE:CONV2;
170       DELAY:ED(5);
180       QUEUE,5;
190       SEIZE:GRAVITY;
200       DELAY:ED(6);
210       QUEUE,6;
220       SEIZE:CONV4;
230       RELEASE:GRAVITY;
240       RELEASE:CONV3;
250       DELAY:ED(7);
260       QUEUE,7;
270       SEIZE:CONV5;
280       RELEASE:CONV4;
290       DELAY:ED(8);
300       QUEUE,8;
310       SEIZE:PISTON;
320       DELAY:ED(9);
330       QUEUE,9;
340       SEIZE:CONV6;
```

```
350         RELEASE:PISTON;
360         RELEASE:CONV5;
370         DELAY:ED(10);
380         QUEUE,10;
390         SEIZE:CONV7;
400         RELEASE:CONV6;
410         DELAY:ED(11);
420         QUEUE,11;
430         SEIZE:LIQUID;
440         DELAY:ED(12);
450         QUEUE,12;
460         SEIZE:CONV8;
470         RELEASE:LIQUID;
480         RELEASE:CONV7;
490         DELAY:ED(13);
500         QUEUE,13;
510         SEIZE:CHECK;
520         RELEASE:CONV8;
530         DELAY:ED(14);
540         BRANCH,1:
              WITH,.05,SCRAP:
              ELSE,CONTINUE;
550 SCRAP     COUNT:3;
560         RELEASE:CHECK:DISPOSE;
570 CONTINUE QUEUE,14;
580         SEIZE:CONV9;
590         RELEASE:CHECK;
600         DELAY:ED(15);
610         QUEUE,15;
620         SEIZE:LIDFID;
630         RELEASE:CONV9;
640         DELAY:ED(16);
650         BRANCH,1:
              WITH,.5,YAGUCHI1:
              ELSE,YAGUCHI2;
660 YAGUCHI1 QUEUE,16;
670         SEIZE:CONV10;
680         RELEASE:LIDFID;
690         DELAY:ED(17);
700         QUEUE,17;
710         SEIZE:YAGUCHI1;
720         RELEASE:CONV10;
730         DELAY:ED(18);
740         QUEUE,18;
750         SEIZE:CONV12;
760         RELEASE:YAGUCHI1;
770         DELAY:ED(19);
780         QUEUE,19;
790         SEIZE:WASHER2;
800         RELEASE:CONV12;
810         BRANCH,1:
              ALWAYS,DELLAY;
820 YAGUCHI2 QUEUE,20;
```

```
        SEIZE:CONV11;
        RELEASE:LIDFID;
        DELAY:ED(20);
        QUEUE,21;
        SEIZE:YAGUCHI2;
        RELEASE:CONV11;
        DELAY:ED(21);
        QUEUE,22;
        SEIZE:CONV13;
        RELEASE:YAGUCHI2;
        DELAY:ED(22);
        QUEUE,23;
        SEIZE:WASHER2;
        RELEASE:CONV13;
DELLAY  DELAY:ED(23);
        RELEASE:WASHER2;
        TALLY:1,INT(1);
        COUNT:2:DISPOSE;
END;
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SIMAN EXPERIMENT PROCESSOR RELEASE 3.0
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BEGIN;
10 PROJECT,ASSEMBLY,DESAI,2/26/86;
20 DISCRETE,1000,2,23;
30 DISTRIBUTIONS:1,CO(1):
                2,UN(2,1):
                3,CO(3):
                4,UN(4,1):
                5,UN(5,1):
                6,CO(6):
                7,UN(7,1):
                8,UN(8,1):
                9,CO(9):
                10,UN(10,1):
                11,UN(11,1):
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                13,UN(13,1):
                14,CO(14):
                15,UN(15,1):
                16,CO(16):
                17,UN(17,1):
                18,CO(18):
                19,UN(19,1):
                20,UN(20,1):
                21,CO(21):
                22,UN(22,1):
                23,CO(23);
    ;           24,EX(24,1);

    ;
40 RESOURCES:1,CONV1,7:
             2,WASHER1:
             3,CONV2,7:
             4,CONV3,5:
             5,GRAVITY:
             6,CONV4,7:
             7,CONV5,5:
             8,PISTON:
             9,CONV6,7:
             10,CONV7,5:
             11,LIQUID:
             12,CONV8,7:
             13,CHECK:
             14,CONV9,7:
             15,LIDFID:
```

```
            16,CONV10,7:
            17,CONV11,7:
            18,YAGUCHI1:
            19,YAGUCHI2:
            20,CONV12,3:
            21,CONV13,3:
            22,WASHER2;
 ;
50 PARAMETERS:1,1.35:
            2,6.9,7.1:
            3,1.0:
            4,6.9,7.1:
            5,4.9,5.1:
            6,1.0:
            7,6.9,7.1:
            8,4.9,5.1:
            9,1.0:
            10,6.9,7.1:
            11,4.9,5.1:
            12,1.0:
            13,6.9,7.1:
            14,1.0:
            15,6.9,7.1:
            16,1.0:
            17,6.9,7.1:
            18,2.7:
            19,2.9,3.1:
            20,6.9,7.1:
            21,2.7:
            22,2.9,3.1:
            23,1.0;
 ;          24,0,0;
60 COUNTERS:1,TOTAL ARRIVALS:
           2,TOTAL DEPARTURES:
           3,TOTAL SCRAPPED;
70 TALLIES:1,TIME IN SYSTEM;
80 DSTAT:1,NQ(1),Q FOR CONVEYOR1:
        2,NQ(2),Q FOR WASHER1:
        3,NQ(3),Q FOR CONVEYOR2:
        4,NQ(4),Q FOR CONV3:
        5,NQ(5),Q FOR GRAVITY FILLER:
        6,NQ(6),Q FOR CONV4:
        7,NQ(7),Q FOR CONV5:
        8,NQ(8),Q FOR PISTON FILLER:
        9,NQ(9),Q FOR CONV6:
        10,NQ(10),Q FOR CONV7:
        11,NQ(11),Q FOR LIQUID FILLER:
        12,NQ(12),Q FOR CONV8:
        13,NQ(13),Q FOR CHECK:
        14,NQ(14),Q FOR CONV9:
        15,NQ(15),Q FOR LIDFID:
        16,NQ(16),Q FOR CONV10:
        17,NQ(17),Q FOR YAGUCHI1:
```

```
        18,NQ(18),Q FOR CONV12:
        19,NQ(19),Q FOR WASHER2:
        20,NQ(20),Q FOR CONV11:
        21,NQ(21),Q FOR YAGUCHI2:
        22,NQ(22),Q FOR CONV13:
        23,NQ(23),Q FOR WASHER2:
        24,NR(1),BUSY CONV1:
        25,NR(2),BUSY WASHER1:
        26,NR(3),BUSY CONV2:
        27,NR(4),BUSY CONV3:
        28,NR(5),BUSY GRAVITY:
        29,NR(6),BUSY CONV4:
        30,NR(7),BUSY CONV5:
        31,NR(8),BUSY PISTON:
        32,NR(9),BUSY CONV6:
        33,NR(10),BUSY CONV7:
        34,NR(11),BUSY LIQUID:
        35,NR(12),BUSY CONV8:
        36,NR(13),BUSY CHECK:
        37,NR(14),BUSY CONV9:
        38,NR(15),BUSY LIDFID:
        39,NR(16),BUSY CNV10:
        40,NR(17),BUSY CONV11:
        41,NR(18),BUSY YAGUCHI1:
        42,NR(19),BUSY YAGUCHI2:
        43,NR(20),BUSY CONV12:
        44,NR(21),BUSY CONV13:
        45,NR(22),BUSY WASHER2;
  ;
90 REPLICATE,1,,10000;
  ;
  ;
  END;
```

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